Hanford Site Environmental Monitoring Plan

Section III.A. Surface Environmental Surveillance

Prepared by: Date:	Concurrence: Date:
R. L. Dirkes, Pacific Northwest National Laboratory	D. C. Ward, U.S. Department of Energy, Richland Operations Office

Introduction

This section describes the Hanford Site plan for surface environmental surveillance. Environmental surveillance includes all components of the surface environment. The purpose of this section is to describe how the surveillance requirements of U.S. Department of Energy (DOE) Orders 5400.1 and 5400.5 and the guidance of DOE/EH-0173T are to be met for the Hanford Site.

The Surface Environmental Surveillance Project, conducted by Pacific Northwest National Laboratory (PNNL) for DOE, is a multimedia environmental monitoring effort to measure the concentration of radionuclides and chemicals in environmental media and assess the integrated effects of these materials on the environment and the public. The project collects samples of air, surface water, sediments, soil and natural vegetation (approximately every 5 yr), agricultural products, fish, and wildlife. Analytical capabilities include the measurement of radionuclides at very low environmental concentrations and nonradiological chemicals, including metals, anions, thioureas, volatile organic compounds, semivolatile organic compounds, pesticides, and polychlorinated biphenyls. In addition, the project includes the capability to measure ambient external radiation.

Activities inherent in the operation of the Surface Environmental Surveillance Project include design and implementation, sample collection, sample analysis, database management, data review and evaluation, exposure assessment, and reporting. Other elements of the project include project management, quality assurance/control, training, and records management.

The project focuses on routine releases from DOE facilities on the Hanford Site; however, the project is also responsive to unplanned releases and releases from non-DOE operations on and near the site. Surveillance results are provided annually through the Hanford Site environmental report (e.g., PNNL-11472). In addition, unusual results or trends are reported to DOE and the appropriate facility managers when they occur. Whereas effluent and near-facility environmental monitoring are conducted by the facility operating contractor, environmental surveillance is conducted under an independent program and reports directly to the DOE-Richland Operations Office (RL) Environmental Assurance, Permits and Policy Division.

Although the scope of the Surface Environmental Surveillance Project has expanded during recent years to include hazardous chemical surveillance, this plan focuses on radiological surveillance in response to DOE requirements. This plan is written to comply with all *should** statements in DOE/EH-0173T unless noted otherwise in the Exceptions discussions. *Should* statements are described in DOE/EH-0173T as flexible guidance; this guidance has been considered in the development of this plan and incorporated where determined appropriate. However, lack of incorporation of such statements has not been noted in the Exceptions discussions.

This section (III.A) of the plan is related to other sections in several respects. The sampling design described is based on radiological and chemical pathway analyses that utilize the source data obtained under the effluent-monitoring program described in Section II.A and the near-facility environmental monitoring program described in Section II.B. The pathway analysis and dose assessment conducted for this plan and the dose assessments reported in the annual Hanford Site environmental report (e.g., PNNL-11472) use the dispersion data provided by the Meteorological and Climatological Services Project described in Section III.C. The pathway analyses and dose assessment conducted for this section include the contribution to dose from the groundwater pathway discussed in Section III.B.

The environmental pathways carrying contaminants to humans and the significance of the media and contaminants to total dose are strongly influenced by the environmental setting. The Hanford Site's environmental setting is summarized in PNNL-6415 Rev. 9 and will not be described here.

Requirements and Objectives

The general requirements and objectives for environmental surveillance are contained in DOE Orders 5400.1 and 5400.5. The broad objectives (DOE Order 5400.1) are to demonstrate compliance with legal and regulatory requirements, to confirm adherence to DOE environmental protection policies, and to support environmental management decisions. These requirements are embodied in the surveillance objectives stated in the DOE Orders and DOE/EH-0173T and include the following:

- determine compliance with applicable environmental quality standards and public exposure limits and applicable laws and regulations; the requirements of DOE Orders 5400.1 and 5400.5; and the environmental commitments made in environmental impact statements, environmental assessments, safety analysis reports, or other official DOE documents. Additional objectives that derive from the DOE Orders and this primary objective include the following:
  - conduct preoperational assessments
  - assess radiological doses to the public and aquatic biota from site operations
  - assess doses from other local sources
  - report alarm levels and potential doses exceeding reporting limits (DOE Order 5400.5, Chapter II, Section 7)
  - prepare an annual site environmental report
  - maintain an environmental monitoring plan
- determine background levels and site contributions of contaminants in the environment
- determine long-term accumulation of site-related contaminants in the environment and predict trends; characterize and define trends in the physical, chemical, and biological condition of environmental media
- determine effectiveness of treatment and controls in reducing effluents and emissions
- determine validity and effectiveness of models to predict the concentrations of pollutants in the environment
- detect and quantify unplanned releases
- identify and quantify new or existing environmental quality problems.

DOE/EH-0173T indicates that subsidiary objectives for surveillance should be considered. Subsidiary objectives applicable to the site include the following:

- obtain data and maintain the capability to assess the consequence of accidents

- provide public assurance; address issues of concern to the public, business, and regulators

- enhance public understanding of site environmental impacts, primarily through public involvement and by providing public information

- provide environmental data and assessments to assist DOE-RL in environmental management of the site.

The DOE Orders require that the content of surveillance programs be determined on a site-specific basis by DOE-RL. The surveillance programs must reflect facility characteristics; applicable regulations; hazard potential; quantities and concentrations of materials released; extent and use of affected air, land, and water; and specific local public interest and concern.

Surface Environmental Surveillance Design

DOE Orders 5400.1 and 5400.5 require that the content of surveillance programs be determined on a site-specific basis by DOE-RL. The surveillance programs must reflect facility characteristics; applicable regulations; hazard potential; quantities and concentrations of materials released; extent and use of affected air, land, and water; and specific local public interest and concern. Environmental surveillance is designed to meet the listed objectives while considering the environmental characteristics of the site and potential and actual releases from site operations. Surveillance activities focus on determining environmental impacts and compliance with public health and environmental standards or protection guides rather than on providing detailed radiological and chemical characterization. Experience gained from environmental surveillance activities and studies conducted at the Hanford Site for more than 50 yr provide valuable technical background for planning the surveillance design.

This subsection discusses the rationale and criteria, surveillance design, and annual surveillance design-review process.

Rationale and Design Criteria

The rationale and criteria for environmental surveillance are based on the following:

- DOE Orders 5400.1 and 5400.5
- DOE/EH-0173T
- surveillance objectives
- results of the radiological and chemical pathway analyses
- other site commitments.

The minimum objective criteria for determining the content of surveillance projects are contained in Tables 5-1 and 5-2 of DOE/EH-0173T and Table 4 of Section 7 of EPA-520/1-80-012.

Based on current doses and the above-referenced objective criteria alone, periodic surveillance measurements are required a minimum of every 5 yr to confirm that the doses are below the objective criteria.

However, conducting only confirmatory surveillance measurements every 5 yr at the site and in the surrounding region would not fully meet the primary surveillance objectives (see Requirements and Objectives) or satisfy the subsidiary objectives. The rationale and criteria for additional sampling in each medium will be discussed in the subsections that follow. First, there are some general considerations that will be factors in decisions about the content of the surveillance design.

The application of objective criteria from DOE/EH-0173T to the radiological pathway analyses results addresses only surveillance for routine releases and does not consider the inventory potentially available for release. The potential inventory of activity disposed to the ground is very large (5.6 million Ci). In addition, it is estimated that there are 209 million Ci in waste-storage tanks, 174 million Ci (cesium and strontium) in capsule storage, 63 million Ci in irradiated fuel, 651 thousand Ci in stored solids, and 16 million Ci in isotopic heat sources. Likewise, the inventory of hazardous chemicals onsite, while not well quantified or documented, is believed to be of considerable magnitude.

The need for routine surveillance independent of the operating contractor is reinforced by the recognition that expedited cleanup actions under the Hanford Federal Facility Agreement and Consent Order (also known as the Tri-Party Agreement; Ecology et al. 1989) have begun and that cleanup actions will increase and continue over the next few decades. This activity, in some cases applying cleanup technologies that have never been used before, increases the potential for the release to and migration within the environment of materials that are currently well contained. The design for routine surveillance must address the need to establish baselines to measure the integrated effects of various cleanup actions across the site and to monitor the trends that may result from these operations.

Design rationale and criteria that apply to most media are summarized below.

Media Selection

Highest priority is to be given to sampling media that are directly ingested or inhaled by the public. Additional media are selected based on their sensitivity as indicators of loss of control, for their ability to predict accumulations and trends, or as indicators of environmental quality.

Sampling Locations

Background sampling locations are to be established for all media-contaminant combinations routinely sampled or that would likely have to be sampled to assess the effects of unusual or accidental releases. Sampling locations are selected near potential sources to maximize the probability of detecting losses of containment, to establish baselines, and to assess the effects of releases. Sampling stations are positioned at the site perimeter (near or just inside the site boundary) to estimate conditions at the nearest points at which members of the public reside or could reside. Exposures at these locations are typically the maximum that any member of the public could receive. Finally, sampling is conducted in the community locations where the highest potential chronic impacts are expected to occur, both to provide measurements where the most people are potentially exposed and to provide assurance to the communities that levels are well below standards established to protect public health.

Sampling and Analysis Frequencies

Sampling frequency selection is based on the rate at which significant changes are expected and the need to obtain time-representative samples. In general, sampling near onsite effluents will be the most frequent, sampling at the perimeter will be less frequent, and sampling at distant offsite locations will be the least frequent. The exposure or sample integration period may be up to 1 yr but no more than twice the radionuclide half-life. The minimum exposure period must be constrained to the operating limits (flow, breakthrough, etc.) of the sampling medium necessary to obtain a sample representative of the exposure period. Periodic samples are composited for longer-lived radionuclides to increase time representativeness and to lower detection limits.

Detection and Precision

The general surveillance criterion is to use the lowest level of detection practical, utilizing standard analytical procedures and considering practical sampling strategy tradeoffs (e.g., time and location compositing versus discrete samples and practical sampling trains). Where technically feasible and practical, the minimum objective for a given medium-radionuclide combination is to detect concentrations at or below the concentration that would result in a dose to humans of 1 mrem/yr effective dose equivalent (EDE) if that concentration were sustained for a year. This dose estimate assumes that the radionuclide is being transported to subsequent compartments of the pathway and that the individual is exposed to all subsequent compartments. For example, the limit for air assumes not only inhalation but also exposure from deposition, vegetation uptake, consumption, etc. One millirem is selected as the minimum criterion because it is 10% of the level at which potential doses to the public must be reported to DOE-Headquarters (HQ), as well as being 10% of the dose limit (Code of Federal Regulations, Title 40, Part 61 [40 CFR 61]) for the air pathway, thereby providing a high level of assurance that these requirements will be met.

The current detection criteria (by radionuclide and medium) are contained in the subsection entitled Laboratory Procedures. Except for ^{14}C in air, these detection limits are well below the 1-mrem level and are driven by the goal of obtaining the lowest practical level of detection using standard methods. Analytical precision criteria are contained in the subsection entitled Quality Assurance and Quality Control.

The rationale, design criteria, and plan for surveillance measurements to meet the primary and subsidiary objectives are described in the media-specific subsections.

Dose Assessment

Pathway and dose assessments are conducted as follows:

- annually to assess compliance with DOE Order 5400.5 public limit and 40 CFR 61 criteria
- annually to determine the minimum needs for environmental surveillance as defined in DOE/EH-0173T
- at least every 5 yr to assess compliance with DOE Order 5400.5 interim aquatic biota limit or when exposure conditions have changed significantly, at the discretion of the cognizant PNNL manager.

The need for updates to dose assessment codes or input data is controlled through procedures established by the Hanford Environmental Dose Overview Panel (discussed in the subsection entitled

Dosimetry Coordination). The Panel establishes a site policy for reviewing and updating population and pathway data, a frequency for the review of input data, and guidelines for when new data must be incorporated into dose calculations.

Surveillance Design

The Hanford Site Surface Environmental Surveillance Project historically has focused on radionuclides in various media and nonradiological water quality parameters. In recent years, surveillance for nonradiological constituents, including hazardous chemicals, has been expanded significantly. A detailed chemical pathway and exposure analysis for the Hanford Site was completed in 1994 (PNNL-10714). The analysis helped guide the selection of chemical surveillance media, sampling locations, and chemical constituents.

Each year, a radiological pathway analysis and exposure assessment is performed. The pathway analysis is based on source-term data and on the comprehensive pathway and dose assessment methodology included in the Generation II (GENII) computer code (PNL-6584) used for estimating radiation doses to the public from Hanford Site operations. The CRITR computer code (PNL-8150) was used to calculate doses to animals, and manual calculations were used to compute the doses not addressed in the computer codes. The results of the pathway analysis and exposure assessment serve as a basis for future years' surveillance program design.

Exposure is defined as the interaction of an organism with a physical or chemical agent of interest. Thus, exposure can be quantified as the amount of chemical or physical agent available for absorption at the organism's exchange boundaries (i.e., dermal contact, lungs, gut, etc.). An exposure pathway is identified based on 1) examination of the types, location, and sources (contaminated soil, raw effluent, etc.) of contaminants; 2) principal release mechanisms; 3) probable environmental fate and transport (including persistence, partitioning, and intermediate transfer) of contaminants of interest; and, most important, 4) location and activities of the potentially exposed populations. Mechanisms that influence the fate and transport of a chemical through the environment and influence the amount of exposure a person might receive at various receptor locations are listed below.

Once a radionuclide or chemical is released into the environment it may be:

- transported (e.g., migrate downstream in solution or on suspended sediment, travel through the atmosphere, or be carried offsite in contaminated wildlife)
- physically or chemically transformed (e.g., deposition, precipitation, volatilization, photolysis, oxidation, reduction, hydrolysis, or radionuclide decay)
- biologically transformed (e.g., biodegradation)
- accumulated in the receiving media (e.g., sorbed strongly in the soil column, stored in organism tissues).

The primary pathways for movement of radioactive materials and chemicals from the site to the public are the atmosphere and surface water. Figures III.A-1 and III.A-2 illustrate these potential routes and exposure pathways to humans and biota, respectively.

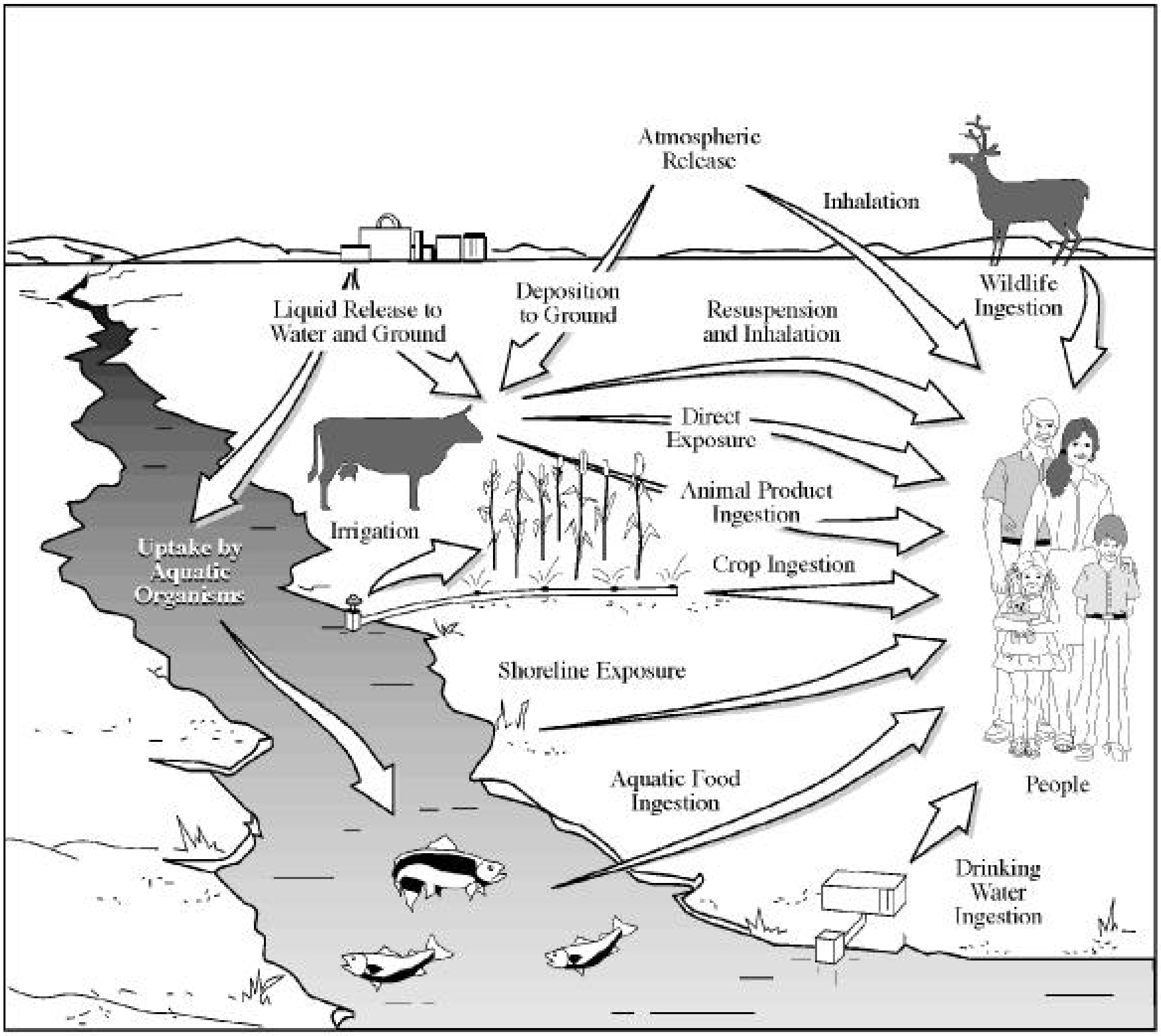

Figure III.A-1. Primary Exposure Pathways to Man

The significance of each pathway is determined from measurements and calculations that estimate the amount of radioactive material or chemical transported along each pathway and by comparing the concentrations or potential doses to environmental and public health-protection standards or guides. Pathways are also evaluated based on prior studies and observations of radionuclide and chemical movement through the environment and food chains. Calculations based on effluent data show the expected concentrations off the Hanford Site to be low for all Hanford-produced radionuclides and chemicals and to be frequently below the level that can be detected by monitoring technology. To ensure that radiological and chemical analyses of samples are sufficiently sensitive, minimum detectable concentrations of key radionuclides and chemicals have been established at levels well below applicable health standards.

Environmental and food-chain pathways are monitored near facilities releasing effluents and at potential offsite receptor locations. The surveillance design uses a stratified sampling approach to monitor these pathways. Samples are collected, and radionuclide and chemical concentrations are measured in three general surveillance zones that extend from onsite operational areas to the offsite environs.

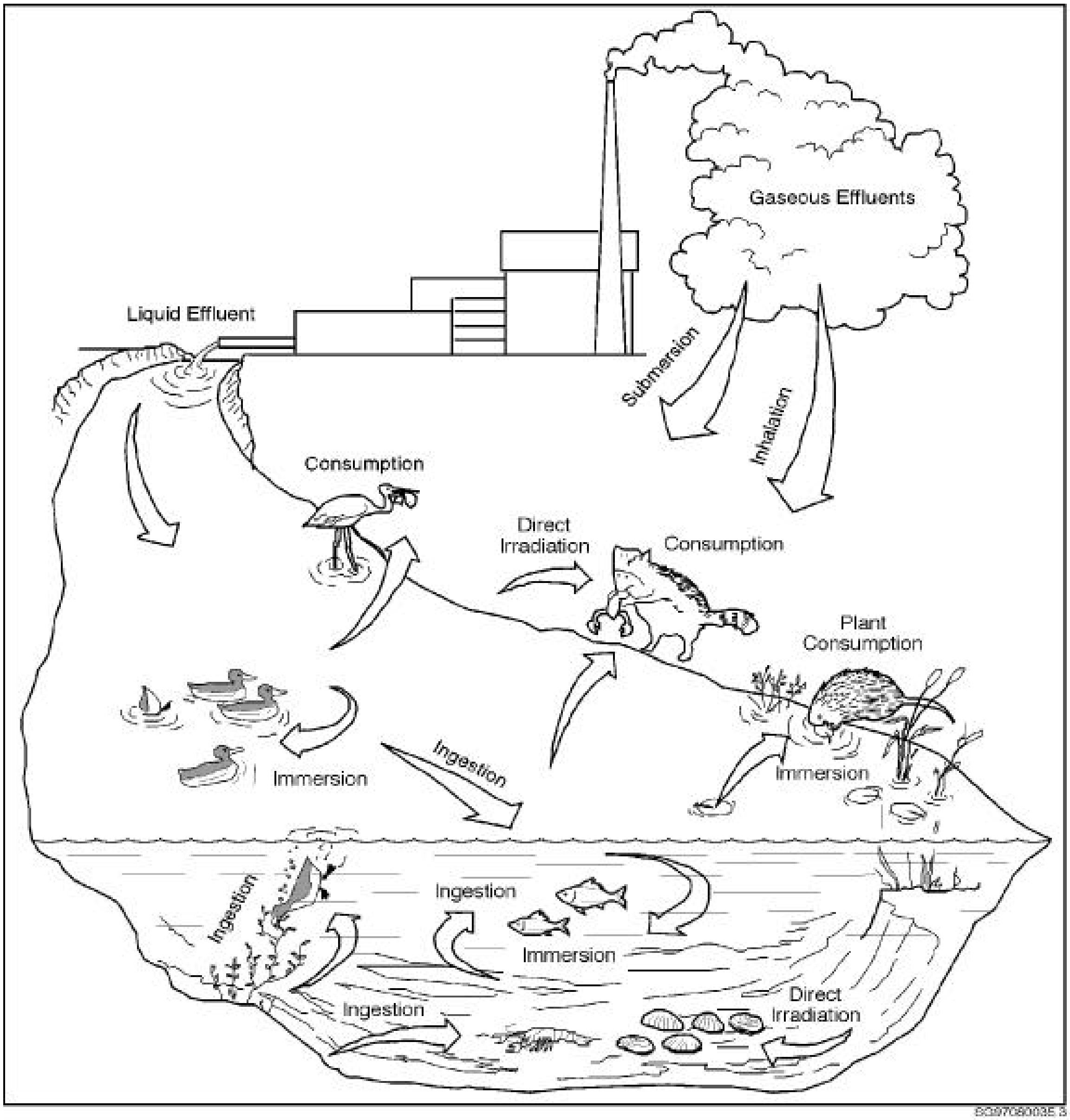

Figure III.A-2. Radiation and Chemical Exposure Pathways to Biota

The first surveillance zone extends from near the operational areas to the site perimeter. The environmental concentrations of releases from facilities and fugitive sources (those released from other than monitored sources such as contaminated soils) generally would be the highest and, therefore, most easily detected in this zone. The second surveillance zone consists of a series of perimeter sampling stations positioned near or just inside the site boundary, along Highway 240, which runs through the site from Richland to the Vernita Bridge, and along the Columbia River. Exposures at these locations are typically the maximum that any member of the public could receive. The third surveillance zone consists of nearby and distant community locations within an 80-km radius of the site. Surveillance is conducted in communities to obtain measurements at locations where a large number of people potentially could be exposed to Hanford Site releases and to document that contaminant levels are well below standards established to protect public health.

Background concentrations are measured at distant locations and compared with concentrations measured onsite and at perimeter and community locations. Background locations are essentially unaffected by site operations (i.e., these locations could be used to measure ambient environmental levels of chemicals and radionuclides). Comparing background concentrations to concentrations measured on or near the site indicates the impact of site operations.

To the extent possible, radiological dose assessments should be based on direct measurements of dose rates and radionuclide concentrations in environmental media. However, the amounts of most radioactive materials released from site operations in recent years generally have been too small to be measured directly once dispersed in the offsite environment. For the measurable radionuclides, often it was not possible to distinguish levels resulting from worldwide fallout and natural sources from those associated with Hanford Site releases. Therefore, offsite doses are estimated using the following methods:

- Doses from monitored air emissions and liquid effluents released to the Columbia River are estimated by applying environmental transport and dose-calculation models to measured effluent-monitoring data and selected environmental measurements. Pathway-modeling results are compared to measurable surveillance results to assess model performance, and the results of the comparison are documented. When measured results exceed model results, the measured results are used to adjust the dose results.

- Doses from fugitive air emissions (e.g., from unmonitored resuspended contaminated soils) are estimated from measured airborne concentrations at site perimeter locations.

- Doses from fugitive liquid releases (e.g., unmonitored groundwater seeping into the Columbia River) are estimated by evaluating differences in measured concentrations upstream and downstream from the Hanford Site.

Annual Design-Review Process

The design of surface environmental surveillance is reviewed annually based on the above considerations as well as an awareness of planned waste-management and environmental restoration activities. The process by which the design is evaluated is both continuous and cyclic. The need for changes in the surveillance design is evaluated continuously during the year in response to changing operations and/or environmental conditions. The design-review process repeats itself each year, using information generated during the previous year as the basis for the evaluation. The final sampling design and schedule are documented annually in the master sampling schedule (e.g., PNNL-11464). Key steps in the process are discussed below.

- pathway analysis - The process starts with the radiological pathway analysis performed by PNNL for the calendar year just ended. This analysis is based on a review and report of facility emissions and effluents provided by Waste Management Federal Services of Hanford, Inc. and PNNL facility managers and the environmental surveillance results from the previous year. The pathway analysis serves as the basis for the annual Hanford Site environmental report (e.g., PNNL-11472) as well as the design review.

- Hanford Site environmental report - The annual environmental report (e.g., PNNL-11472) summarizes the findings of the surveillance activities conducted during the previous calendar year. The evaluation of these results plays an integral part in the design evaluation, both in comparisons with the radiological and chemical pathway analyses conclusions and in identifying changes in environmental conditions that may indicate a need for modifications to the sampling plan. The distribution list for the annual report is reviewed to ensure that potentially affected federal, state, and local governments and agencies; Indian Nations; environmental interests; business interests; and owners of Hanford Reach islands are notified concerning the environmental status of the Hanford Site and its surroundings. Feedback on report contents and areas of concern relative to project design are considered in the design-review evaluation.

- site activity projection - Because the pathway analyses and the annual report are retrospective, an activity projection from the Hanford Site contractors identifies future activities to be considered in terms of surveillance needs. Resources useful in anticipating future environmental surveillance needs include DOE/RL-96-92, DOE/EM-0327, Ecology et al. (1989), various contractor effluent and operational environmental monitoring plans and results from previous years' monitoring, and bimonthly environmental monitoring and characterization technical exchanges between environmental surveillance personnel within each contractor.

- annual surveillance-design evaluation - The above information is considered in the annual surveillance-design evaluation as the basis for planning the surveillance program for the following few fiscal years and/or calendar years. Results of field inspections of sampling and measurement locations conducted during the current year are reviewed to determine whether conditions at sampling locations continue to meet siting and/or sampling design criteria. The design evaluation also includes a review for new surveillance-compliance requirements (e.g., DOE Orders, directives, or other applicable federal or state requirements) and DOE/EH-0173T updates. Plans for the following years are discussed with appropriate Hanford Site contractors to ensure that any assumptions implicit in the surveillance project about the availability of related ambient monitoring data are valid and to determine whether recent ambient data indicate conditions or trends that must be considered in the design of the surveillance project. The results of this annual surveillance-design evaluation and the action, if any, to be taken in response to changes are documented in the administrative files.

- submit scope and budget for upcoming fiscal years - Based on the results of the annual surveillance-design evaluation, the scope and budget information is prepared and submitted for the following few fiscal years. Detail in the out-year scope and budget information is necessarily general in nature; however, it does provide targets on which to base future, more-detailed planning and specific scope and budget development.

- project documentation package for next fiscal year - Specific surveillance objectives, work scope, and budget are provided in the project-specific documentation package written for the upcoming (next) fiscal year. The package sets forth the plans and organization that will be used to conduct, control, and document the project and represents an agreement between DOE-RL and PNNL on the objectives, scope, and work to be performed during that fiscal year.

- scope and budget approval - As defined in the project-specific documentation package, the scope and budget are reviewed and approved by DOE-RL typically during the first half of the current fiscal year. Approval of the scope and budget is documented through DOE-RL signature on the current fiscal year package.

- surveillance design update - The annual surveillance-design evaluation is documented through updates to the project documentation package and the environmental surveillance master sampling schedule (e.g., PNNL-11464). Plans for the following calendar year are developed and discussed with other contractors to coordinate related activities. Plans are also discussed with representatives from the State of Washington Department of Health to identify those samples to be included in the cooperative duplicate sampling program.

- develop next calendar year master surveillance schedule - The master sampling schedule (e.g., PNNL-11464) for the next calendar year, based on the results of the annual design-review process, is prepared and issued.

- environmental monitoring plan update - This *Environmental Monitoring Plan* is reviewed annually and updated every 3 yr (DOE Order 5400.1). Minor annual adjustments in sampling schedules, locations, or methodologies do not warrant revision of the plan but are documented in the project documentation package and master sampling schedule.

Air Surveillance

Radioactive particles and gases are released from point sources (stacks and vents) during routine operations in the 100, 200, 300, and 400 Areas. Diffuse sources consist primarily of contaminated soil in the 100, 200, 300, and 600 Areas that can be resuspended by wind. These materials are diluted to low concentrations as they are transported offsite where people may be directly exposed to radionuclides through inhalation or by deposition onto farm crops, native vegetation, and surface soil.

Each year, a radiological pathway analysis and exposure assessment is performed. Recent pathway analyses indicate that the site dose to the maximally exposed individual (below 0.05 mrem in 1996) is well below the level at which routine surveillance is recommended (DOE/EH-0173T). The predominant air pathways are inhalation and air-food.

The pathway analysis does not include the effects of resuspension of radionuclides from contaminated surfaces. Fission product and transuranic surface contamination exists in the 200 Areas, and uranium surface contamination exists in and around the 300 Area. There is also a large inventory of buried wastes in the 100, 200, and 300 Areas that represents a potential source not addressed in the pathway dose assessment. Past monitoring data indicate that these sources currently do not represent significant sources for the air pathway. However, because of the large inventory, the potential for biointrusion, and the desire to provide a high level of public assurance, continued routine air surveillance of these source areas is considered necessary to provide an early indication of any loss of control. Each of these areas also contains *Comprehensive Environmental Response, Compensation, and Liability Act of 1980* (CERCLA) operable units at which buried wastes will potentially be treated or removed in the future. Air surveillance at the margins of these operable units will provide baseline data before restoration actions (preoperational data) are taken, as well as data to assess the effects of restoration activities.

A review of DOE’s site emergency response plans indicates that each of the four operating areas (100, 200, 300, and 400 Areas) has the potential to initiate a site emergency. Under that designation, there is a potential for an offsite dose of 50 to 1,000 mrem EDE. At this level, there exists a need for near-facility air data to assess impacts resulting from potential accidents and unusual occurrences. To meet these special sampling needs, air samplers must be operated continuously.

Public assurance is an essential element of surveillance at the Hanford Site. Although pathway modeling using operating facility source-term data is a useful tool, the public inherently has more confidence in actual environmental measurements. Sampling near the site perimeter, especially in the downwind sectors, provides data that are compared to background data to estimate the effect of the site at the closest point of actual or potential public residence, as well as to evaluate the pathway models and to estimate doses directly. Measurements in nearby communities provide assurance at those locations where the greatest number of people reside. In many cases, the environmental levels are currently below analytical detection limits. Exposures at the detection limits would result in doses that are a very small fraction of the dose standards.

Objectives

The objectives of air surveillance are the following:

- obtain air-concentration measurements at locations of actual and potential public residence to verify that doses to the public through the air pathway from DOE operations remain low relative to standards
- provide early detection of potential increases in public exposures and contamination of the environment through measurements of actual and potential emissions to the air from facilities and areas with surface contamination and buried wastes
- obtain preoperational baseline data and environmental surveillance data for areas near waste units scheduled for treatment and/or restoration to assess the integrated effects of individual site actions and over time
- obtain measurements at the site perimeter and in nearby communities to provide public assurance that the degree of contamination from DOE operations is known
- sample air onsite and offsite continuously to assess the environmental effects and doses from unusual releases
- provide data to evaluate and improve pathway models used to predict and assess public dose compliance and environmental contamination
- conduct surveillance for Fast Flux Test Facility technical specifications (HEDL 1981).

Plan Rationale and Criteria

The criteria for air sampling consist of those identified in DOE/EH-0173T. The actual level of surveillance and specific criteria to meet the site objectives are described below.

The locations, media, sampling frequencies, temporal and spatial compositing, analyses, and analysis frequencies to meet air-surveillance objectives and criteria are given in the annual sampling schedule (e.g., PNNL-11464). The 1997 sampling locations are provided in Figure III.A-3. Sample locations may change annually. The rationale and any additional specific criteria for these selections are discussed below.

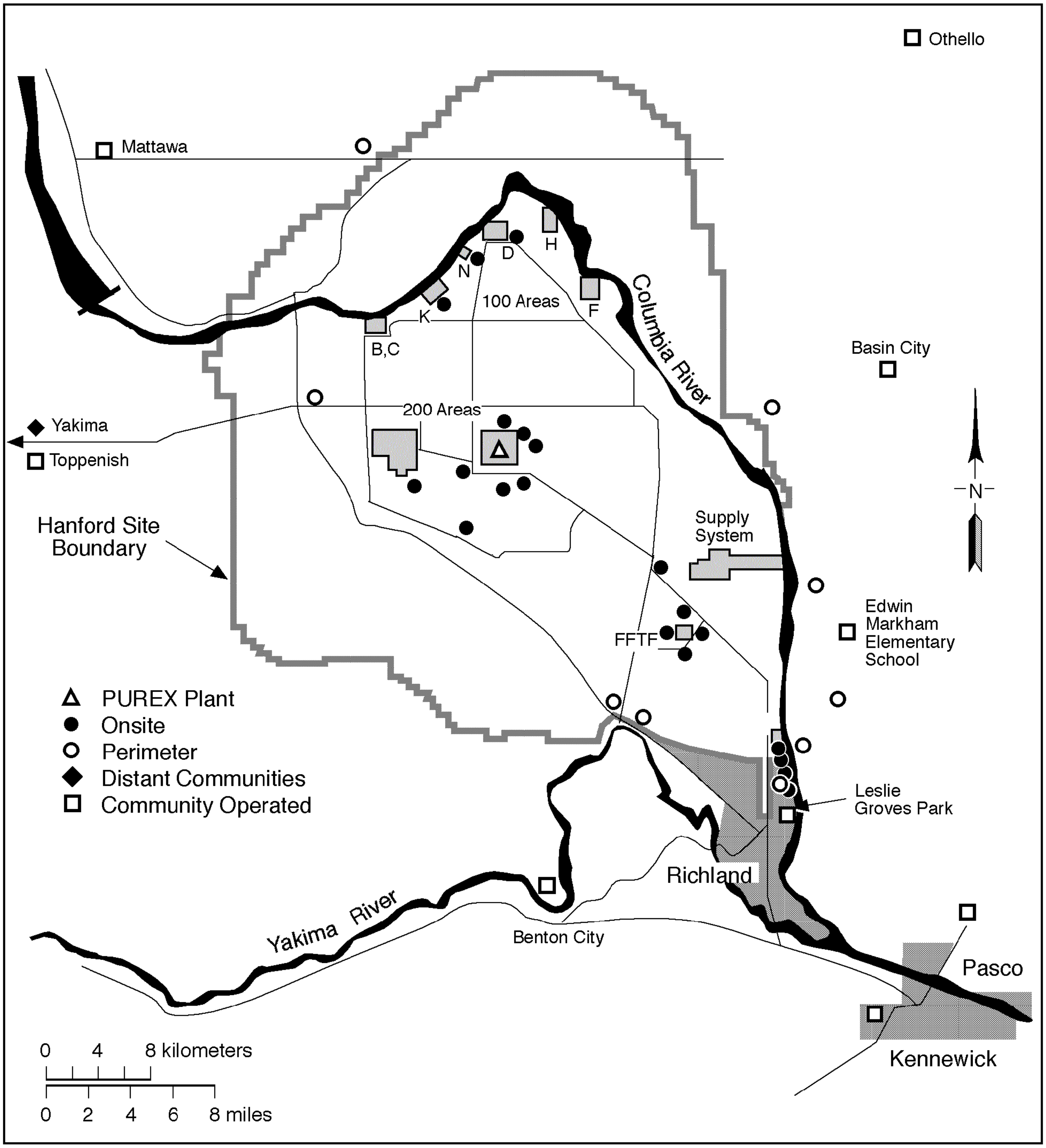

Figure III.A-3. Air-Sampling Locations

Media Selection

Air is sampled according to the primary form in which the radionuclides occur. Most of the radionuclides of interest occur in particulate form at the site. Past measurements indicate that iodine occurs predominantly as a gas and tritium as water vapor.

Analyte Selection

Onsite. Air samples collected downwind near each operating area are field surveyed for alpha and beta-gamma radioactivity with hand-held instruments at the time of collection to verify normal conditions or to detect unusual conditions should they occur. These samples are then analyzed for gross alpha and beta activity after natural activity has decayed to provide an indication of the levels of contaminants present. The samples are then composited and analyzed for those radionuclides routinely released in measurable quantities as indicated by facility emissions data, for those with potential to be released under plausible abnormal conditions, for those calculated to contribute more than 10% of the maximally exposed individual dose, and for those of special public or agency interest. These criteria encompass those radionuclides considered necessary to meet technical and public assurance objectives. Compositing and screening techniques may be used to improve detection levels and reduce analysis requirements where screening provides adequate surveillance.

Perimeter. Additional samples are collected near the perimeter of the site, in the downwind direction, and are used to assess operational control and effects of unusual events. These samples are field surveyed and laboratory analyzed for gross alpha and gross beta and are composited to enhance detection sensitivity for gamma-emitting radionuclides and other radiochemical analyses.

Offsite. Samples from the historical maximally exposed individual locations and downwind contaminants are analyzed for measurable radionuclides, those contributing more than 10% of the maximally exposed individual dose, and those of special public or agency interest.

Sampling and Analysis Frequency

Sample locations are visited every other week. Site experience indicates that particulate filters must be collected at this frequency to avoid excess particulate buildup on the filters. Particulates are analyzed for gross alpha and gross beta every other week to provide early indication of any loss of control that may require expedited analysis of samples and/or additional or special sampling. Gamma scans are analyzed quarterly to track trends that are not likely to be detectable in gross activity measurements. Radiochemical analyses (i.e., isotopic uranium, isotopic plutonium, and ^{90}Sr) of filters are performed annually to provide data to estimate or bound the human annual dose standards.

Iodine-131 charcoal cartridge samples are no longer routinely collected. With the shutdown of all reactors and fuel reprocessing, there is no active DOE source of this radioisotope. Any ^{131}I released to the environment from past DOE operations would have decayed to undetectable amounts.

Iodine-129 charcoal cartridges and tritium silica gel columns are collected monthly. This is an operationally practical sampling period and has been observed to be short enough to preclude significant breakthrough and loss of sample. Samples are analyzed monthly for tritium. Iodine-129 is the leading contributor to dose through the air pathway. Monthly samples are composited and analyzed quarterly near the source (200-East Area) and at the perimeter and background locations to track shorter-term trends.

Background locations are sampled for a given constituent at the highest frequency the constituent is sampled onsite or offsite so that data can be compared and analyzed on the same time scale. The sampling schedule is evaluated and prepared annually.

Sampling Location Selection

Onsite. Downwind of each operating area with significant inventories of nuclear materials, an air sampler is located as near the climatologically predicted maximum impact area as is practical (considering access, power availability, and costs). Additional samplers are located around those areas to increase the likelihood of detecting an unusual occurrence. These additional samplers are distributed azimuthally by wind-direction sector, balancing considerations of wind-direction frequencies, geometric distribution, and practicality. Radial placement is based on the predicted distance of maximum ground-level impact for Class E atmospheric stability (slightly stable) (from Turner 1970, Figure 3-9) to the extent practical. The goal of placing samplers at the Class E stability maximum ground-level impact distance is a compromise between the desire to sample at the point of maximum ground-level concentration for all stabilities; the desire to be far enough away that an elevated plume will reach the ground at the sampler under all conditions; and the practical recognition that, in general, power is available near the facilities and much less available at increasing distance from the facilities.

Samplers are located with the goal of providing measurements representative of the integrated effects of the areas being monitored, a goal that may require a tradeoff with the goal of measuring the maximum effects.

Perimeter. Additional stations at the perimeter of the site are located to reflect the distribution of source areas across the site.

Offsite. Offsite samplers are located near the maximally exposed individual location to attempt to verify such exposures; in the nearest downwind population center, the Tri-Cities, to bound the maximum exposures at the nearest population center and at the highest frequency wind-direction sectors. In addition, samplers are located in a few selected downwind communities to provide means for public involvement, education, and assurance.

At least one background location a minimum of 20 km from the site in a predominantly upwind direction is sampled for each radionuclide, form, and species sampled onsite or offsite.

Proximity to Obstructions. Samplers are located to obtain concentration measurements representative of open areas (i.e., avoiding significant local effects on the radionuclide concentrations of interest such as those caused by building wake entrainment and vegetation filtration). This approach is expected to provide better comparability of data between locations.

Samplers are placed outside building wake zones, where aerodynamic effects could significantly affect the observed concentrations. This can occur when elevated plumes pass over structures and are entrained and mixed into the wake or when plumes are of the same order or size as the structures they impinge upon. In the latter case, plumes will have a strong concentration gradient, and mixing by a wake can significantly change the concentrations that would otherwise have been observed. After elevated plumes have contacted the ground and at distances where the lateral dimensions of the plume are large compared to structures, the effects of the structures on air concentrations about the structures can be expected to be small because the concentration gradients in the air approaching the structure are small. To implement this qualitative model, samplers are located at a distance that is at least three times the height of the building away from the nearest building unless:

- the sampling point is farther from the source than the predicted distance for the ground-level maximum concentration for the applicable effective stack height under Class F atmospheric stability (from Turner 1970, Figure 3-9)

- the lateral plume width (4 x σy from Turner 1970, Figure 3-2) under Class F atmospheric stability (moderately stable) conditions is at least 10 times L, where L is the largest dimension of the building.

Samplers near trees or other elevated vegetation can be influenced by the same effects. Isolated trees can be expected to cause less flow obstruction but can represent greater sinks for some radionuclides. Based on these considerations, samplers are placed at a distance at least two times the height of isolated trees and at three times the height of rows or stands of trees at all locations.

Application of these criteria is necessarily constrained by accessibility and the cost of providing electrical power. At some locations, it may not be practical to meet the desired criteria.

Sampling inlets are located 2 m above the ground to provide measurements representative of radionuclide concentrations inhaled by humans.

Sampling or Measurement Method Selection

Particle sampling is accomplished with glass fiber filters with manufacturer's documentation of a sampling efficiency of at least 99% for 0.3-micron dioctyl phthalate particles at the flow rate being used (2.6 to 5.2 m^3/h).

When ^{131}I analysis might be necessary, samples are collected on activated charcoal with manufacturer-documented collection efficiencies for the flow rate (2.6 m^3/h), bed depth (2.5 cm), and exposure periods used (14 d). Samples for ^{129}I analysis are collected on petroleum-based (low-background) charcoal specially prepared by PNNL; the collection efficiency is verified; and the flow rate is 2.6 m^3/h, with a bed depth of 2.5 cm, and an exposure period of 28 d. Both types of iodine sample traps are preceded in the sampling train by a disposable filter to remove particles.

Samples for tritium analysis are collected on silica gel for identifying the tritiated water in air component. Flow rates (0.011 m^3/h), media volumes, and exposure periods (28 d) are such that the media are not likely to be saturated during the sampling period. Silica gel saturation is monitored using a color-change indicator, which is useful in diagnosing sampling problems.

Flow rates for air samples are measured at the beginning and end of each sampling period with a device with a documented accuracy of ±20%.

Sample-Handling/-Treatment Methods

Air samples are collected in a manner that avoids loss of sample mass, crosscontamination, or mis-identification. This is accomplished by exchanging whole sample collection media containers, rather than handling the collection media in the field, and by labeling and sealing or storing each sample so that sample integrity as it is collected in the field is maintained. Sample-collection and -handling procedures are described in PNL-MA-580, Rev. 2.

Analytical Methods

Analytical methods are selected to meet the minimum goal of detecting levels equivalent to a dose of 1 mrem if that concentration were sustained for a year. An additional goal is to achieve the lowest detection levels available using standard state-of-the-art analytical methods. The detection levels and analytical methodology are summarized in the subsection entitled Laboratory Procedures.

Quality Control Methods

Air surveillance is controlled under the overall project quality assurance and analytical control program described in the subsection entitled Quality Assurance and Quality Control.

Reporting/Alarm Levels

Anomalous results are flagged by computer screening of reported data as they are entered into the project database. Levels for reporting to DOE-RL have been established and are listed in the subsection entitled Records Management and Reporting. Reporting levels are equivalent to the concentration that might lead to a maximally exposed individual dose of 1 mrem EDE if it were sustained for a year. This reporting level provides early indication of conditions that might eventually require reporting to DOE-HQ, as required by DOE Order 5400.5.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Surface-Water Surveillance

The Columbia River flows through the northern edge of the Hanford Site and forms part of the site's eastern boundary. The Hanford Reach of the Columbia River extends from Priest Rapids Dam to the head of Lake Wallula (the impoundment created by McNary Dam). Priest Rapids Dam is the nearest dam upstream of the site and McNary Dam is the nearest downstream.

In addition to the Columbia River, other surface waters exist at the Hanford Site. These include a naturally occurring pond (West Lake), Rattlesnake Springs, and two intermittently flowing streams (Dry and Cold Creeks), as well as other small springs on the Fitzner/Eberhardt Arid Lands Ecology Reserve. Riverbank springs (i.e., groundwater discharge) occur along the Hanford Reach of the Columbia River as well. Other surface waters include several artificial waste-disposal ponds and a series of ditches also associated with waste-disposal practices at the Hanford Site.

The Columbia River has been developed extensively for hydroelectric power, flood control, navigation, irrigation, and industrial water supplies. The river is used as a source of drinking water at onsite facilities as well as at communities located downstream of the site. In addition, the river and its shoreline are used for a variety of recreational activities, including hunting, fishing, boating, water skiing, wind surfing, picnicking, and swimming.

Pollutants resulting from past and current operations at the Hanford Site, both radiological and non-radiological, are known to enter the Columbia River. In addition to U.S. Environmental Protection Agency (EPA)-permitted direct discharges of liquid effluents from onsite facilities, contaminants from past waste-disposal practices seep into the river through riverbank springs and subsurface groundwater discharges.

The surface-water pathway (Columbia River) has consistently been one of the primary contributors to the potential dose received by the public as a result of operations at the Hanford Site.

Discharges to the Columbia River and onsite waste-disposal ponds are monitored by Fluor Daniel Hanford, Inc. (and its enterprise companies). Requirements of DOE/EH-0173T identify the need for monitoring two media in the pathway of concern (one of which can be the effluent) as part of the routine surveillance program. As such, periodic sampling of the onsite waste-disposal ponds is conducted as part of the surface surveillance conducted by PNNL. Such sampling also provides a means of verifying existing effluent-control and effluent-monitoring systems. Unplanned releases may also be detected through routine sampling of these media.

Site-specific surveillance identified the need to maintain elements of the program to evaluate long-term trends and to detect changes in environmental conditions as a result of Hanford Site operations. In addition, it is essential that the location and concentrations of contaminants entering the Columbia River be known. Periodic sampling of riverbank springs verifies the levels of contaminants identified in the local groundwater and confirms the discharge of certain constituents into the river. Activities designed to provide these capabilities are maintained as appropriate.

The State of Washington classified the stretch of the Columbia River from Grand Coulee Dam to the Washington-Oregon border, which includes the Hanford Reach, as Class A, Excellent (Washington Administrative Code [WAC] 173-201A). Water quality criteria and water use were established in conjunction with this designation. Water quality monitoring is necessary to determine compliance with these criteria.

The Columbia River and the potential impact of Hanford Site operations on the quality of river water have received increasing public scrutiny and concern during recent years. Public-interest groups conducted surveillance along the Hanford Reach and raised many questions and concerns. Surface water-surveillance activities initiated in the past to address such public concerns and to provide public reassurance will be continued.

Objectives

The objectives of the surface water-surveillance activities include the following:

- assess impacts of Hanford Site operations on the water quality of the Columbia River
- identify significant changes in the concentrations of contaminants (radiological and chemical) in surface water
- verify adequacy of effluent monitoring and controls
- characterize contaminants in the surface-water environment
- determine status of compliance with applicable water quality standards
- provide public reassurance that risks associated with the use of the Columbia River are low and are being evaluated on a continuous basis.

Plan Rationale and Criteria

The basis for the design of the surface water-surveillance program is discussed in DOE/EH-0173T. In addition, other environmental monitoring guides and references were considered in the development of the Hanford Site's surface water-surveillance program. Similarly, references and guidance specific to water quality monitoring and water sample collection were used in sampling protocols.

The surface water-sampling plan is summarized annually (e.g., PNNL-11464). The media, locations, sample types, frequency, and analyses are included in the sampling schedule.

All surface-water samples are collected in accordance with documented, reviewed, and approved collection procedures. Applicable sample-collection procedures are described in PNL-MA-580, Rev. 2. As part of the overall Hanford Site environmental monitoring effort, selected duplicate samples are collected with the State of Washington Department of Health (see PNNL-11464).

Media Selection

As previously discussed, contaminants are known to enter the Columbia River as a result of past and current operations at the Hanford Site. Consumption of water or biota from the Columbia River or foodstuffs produced on land irrigated with river water could expose the public to these contaminants. Similarly, public exposure could occur by direct exposure from water recreation. The Columbia River is routinely monitored to measure the potential exposure from these pathways.

Riverbank springs (groundwater discharge) containing contaminants enter the river along the Hanford Reach. The springs are monitored periodically to document the locations and levels of contaminants entering the river. Such monitoring also confirms the findings of the Groundwater Monitoring Project relative to the extent of the contaminated groundwater plumes at the Hanford Site.

Onsite ponds, while not directly accessible to the public, are used by migratory waterfowl and wildlife that could migrate off the site and be harvested and consumed by the public. Onsite ponds are monitored to determine the potential for exposure to the public from this pathway.

Offsite irrigation water may be impacted by site operations. Public concerns with respect to the quality of irrigation water systems and the potential for degradation as a result of site activities have been expressed. Periodic monitoring provides reassurance that irrigation water quality is not impacted by Hanford Site operations.

The following provides a description of the monitoring activities specific to each medium identified above.

Columbia River

Analyte Selection. Columbia River water samples are analyzed for those constituents that, as determined by pathway analyses, represent a significant fraction of the potential dose from the water pathway. In addition, contaminants of public concern are included in the analyses. In general, analyses include those contaminants known or suspected to be present in the river water as a result of past or current Hanford Site operations. In those cases where constituents have been documented to be consistently below measurable levels, they have been removed from the sampling plan.

Radiological analyses of water samples include gross alpha, gross beta, gamma scan, tritium, isotopic uranium, ^{90}Sr, ^{99}Tc, ^{129}I, and $^{239,240}Pu$. Gross alpha and gross beta measurements provide a general indication of the radioactive contamination. Gamma scans provide the ability to monitor for numerous specific gamma-emitting radionuclides, including ^{60}Co, ^{106}Ru, ^{125}Sb, ^{137}Cs, and ^{154}Eu, as well as others. Highly sophisticated radiochemical analytical techniques and, in some cases, special sampling techniques are used to determine the concentrations of tritium, ^{90}Sr, ^{99}Tc, ^{129}I, ^{234}U, ^{235}U, ^{238}U, and $^{239,240}Pu$ in river water. Radionuclides of interest are selected based on their importance in determining water quality, in verifying effluent-control and -monitoring systems, and in determining compliance with applicable standards. Where warranted, the half-lives of specific radionuclides are considered in determining sampling and analysis frequencies.

Chemical contaminants analyzed for in water samples include volatile organic compounds, metals, and anions. In addition to monitoring conducted by PNNL, water quality measurements are also performed by the U.S. Geological Survey in conjunction with the National Stream Quality Accounting Network (NASQAN). The U.S. Geological Survey samples are analyzed for numerous physical, biological, and chemical constituents, including temperature, pH, turbidity, dissolved oxygen, suspended solids, dissolved solids, conductivity, hardness, alkalinity, phosphorus, chromium, iron, and nitrate.

Sampling Location Selection. Routine Columbia River water sample-collection locations are identified in Figure III.A-4. Samples are collected upstream of Hanford Site facilities at Priest Rapids Dam and near the Vernita Bridge to provide background data from locations unaffected by site operations. Samples are collected downstream of Hanford Site facilities at the Richland Pumphouse to identify any increase in contaminant concentrations caused by site operations. The Richland Pumphouse, operated by the City of Richland, is the first downstream point of river-water withdrawal for a public drinking water supply. As such, this location provides an upper estimate of the amount of radioactive material in the water supply of the potentially affected population group(s) downstream of the Hanford Site.

Priest Rapids Dam is located ~8 km upstream of the site boundary and 20 km upstream of the 100-B,C Area. The water sampler at Priest Rapids Dam is positioned approximately midstream within the dam and collects water from the reservoir behind the dam. The Vernita Bridge sampling location is ~6 km upstream of the 100-B Area.

The Richland Pumphouse is located ~3 km downstream of the site boundary and ~5 km downstream of the effluent discharge farthest downstream. The water-sampling intake is located with the City of Richland drinking water supply intake on the Benton County shoreline, ~9 m into the river. Historical environmental monitoring reports indicate this to be the drinking water supply having the maximum radionuclide concentrations downstream of the Hanford Site (BNWL-90, BNWL-316, BNWL-439, BNWL-983, BNWL-1341, BNWL-1505, BNWL-1669, HW-80991). Past sampling along transects near this location indicated that concentrations of gross beta activity and tritium are slightly elevated near the Benton County shoreline (HW-69369, PNL-8531). In 1997, water samples collected at the Richland Pumphouse had statistically elevated concentrations of tritium and ^{129}I compared to samples collected at Priest Rapids Dam (PNNL-11472).

Transect sampling is conducted near the Vernita Bridge, 100-N Area, 100-F Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse. Transect sampling is performed to determine the

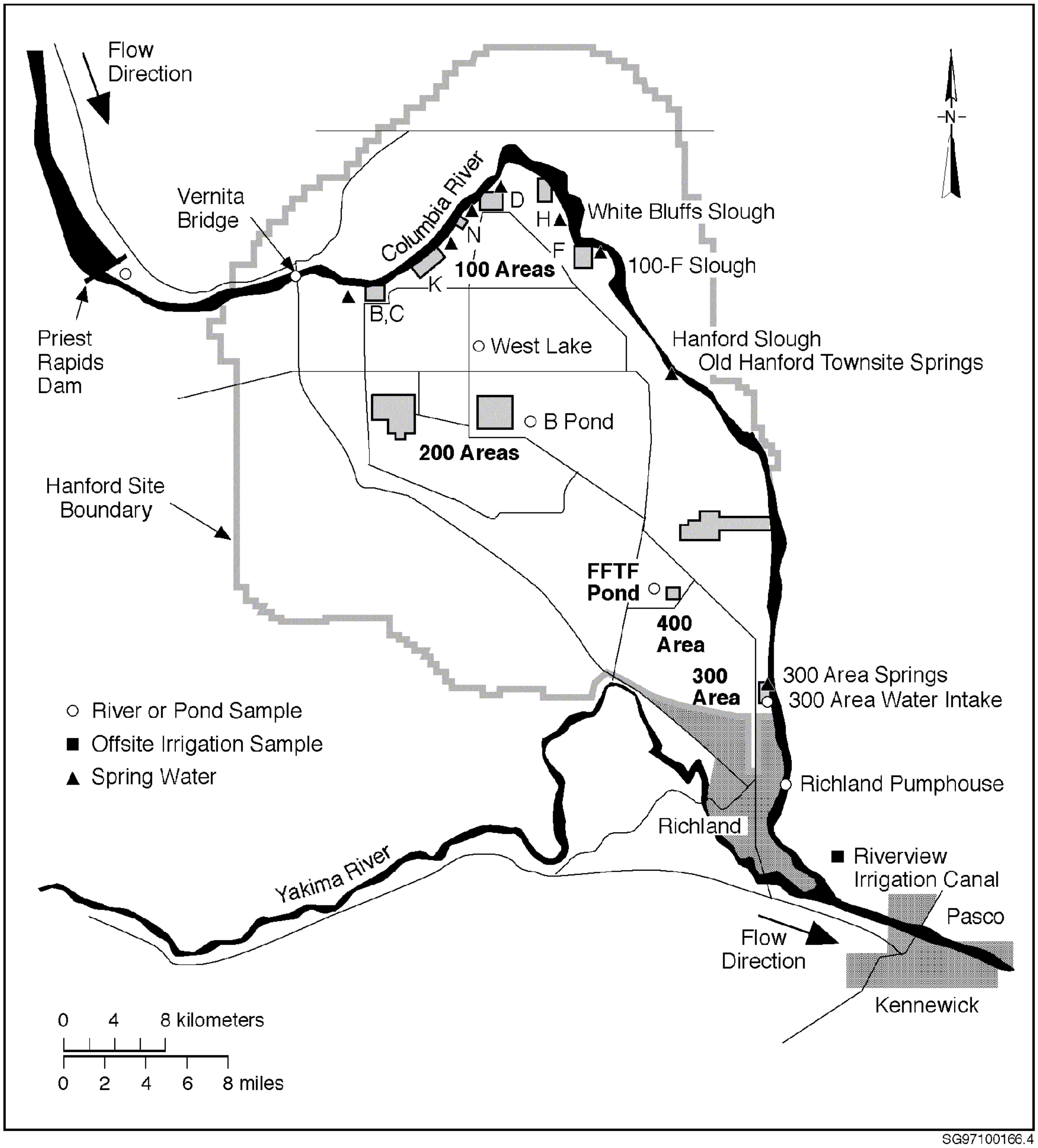

Figure III.A-4. Surface Water-Sampling Locations

distribution of contaminants across the river at these locations. In addition, transect sampling is used to determine the localized zone of influence near known discharges of contaminated groundwater via river-bank springs. The representativeness of the single-point-intake sampling system located at the Richland Pumphouse is also evaluated using results of the transect sampling. Samples along the transects are collected at approximately mid-depth and at several points (up to 10) across the river. Transect sampling will identify those contaminants that are measurable in the river and which may be influenced by proximity to the contaminated groundwater plume.

Sampling or Measurement Methods Selection. The sample types, collection method, sample size, and sample and analysis frequency are discussed below. The selection of sampling methods and equipment depends on the potential for fluctuations in contaminant concentrations, variability in the effluent release into the receiving water, potential for significant environmental or human impact, and characteristics of the contaminant of interest.

Two types of water-sampling systems are used to collect radiological samples: 1) a cumulative system that collects a fixed volume of water at set intervals at each location during each sample period and 2) a specially designed system that continuously collects waterborne radionuclides from the river on a series of filters and mixed-bed ion-exchange resin column. Flow-proportional sampling is desired; however, because of the extremely large size of the Columbia River, such a system is not practical. Manual composites are collected in those cases where the use of automatic units is not feasible and to cover periods of equipment downtime. Sample size is determined by the requirements of the analytical method to be used and the required levels of sensitivity.

Cumulative sampling systems are operated at Priest Rapids Dam and the Richland Pumphouse and consist of timer-activated units that periodically collect water from a continuously flowing substream of Columbia River water into a 10-L container. The sample sequence includes a pre- and post-subsample air purge to avoid crosscontamination between the individual sample aliquots. The cycle is repeated throughout a 1-wk sample period at Priest Rapids Dam and Richland Pumphouse, such that ~55 mL of water are collected every hour. The 10-L sample container is changed every week, and the sample is taken to the laboratory, where water from each location is composited over a 4-wk period, resulting in a total sample size of ~40 L. Analyses are performed on these samples according to the current sampling schedule (e.g., PNNL-11464).

Continuous sampling systems are located at Priest Rapids Dam and Richland Pumphouse. A special, continuously flowing system is used to separate radionuclides from the river water before analysis. A large volume of water is required to allow the extremely small concentrations of these radionuclides to be detected. River water is pumped through the collection system at a rate of ~50 mL/min, resulting in a total sample volume of ~1,000 L during each 2-wk sampling period. Suspended particles >0.45 µm in diameter are removed on a series of filters. Soluble radionuclides, except tritium, are collected on a mixed-bed ion-exchange resin column. The filters and ion-exchange resin are changed every 2 wk, composited by location, and analyzed on a quarterly basis according to the current sampling schedule (e.g., PNNL-11464).

Grab samples of Columbia River water are collected quarterly or annually along crosssections at transect sites near the Vernita Bridge, 100-N Area, 100-F Area, Old Hanford Townsite, 300 Area, and Richland Pumphouse for analyses of various radiological and nonradiological water quality parameters. The requirement for minimum holding and transport times prohibits the use of composite systems for these analyses. Special care is taken to obtain water from a flowing portion of the river, avoiding stagnant backwater areas. Surface debris and bottom sediment are also avoided during sampling by collecting the samples from approximately mid-depth. Samples are delivered to the laboratory, where processing is initiated promptly to ensure sample integrity. Samples are analyzed according to the current sampling schedule (e.g., PNNL-11464).

In addition to monitoring conducted by PNNL, water quality measurements are also performed by the U.S. Geological Survey at Vernita Bridge and Richland. These samples are collected every other month at the Vernita Bridge and quarterly at Richland. Numerous physical, biological, and chemical constituents are analyzed for by their laboratory in Denver, Colorado. In addition to sampling, the U.S. Geological Survey provides flow-rate measurements at the Priest Rapids Dam gauging station, near the upstream boundary of the site.

Sample-Handling/-Transport Methods. Surface-water samples are collected in such a manner as to ensure that the sample is representative of the body of water being sampled. Steps are incorporated in the sampling procedure to avoid misidentification and crosscontamination of the samples being collected. Quality assurance is established and implemented by PNNL's Standards-Based Management System (PNNL 1997). Chain-of-custody procedures, to ensure the integrity of the sample throughout the collection-transport-analysis process, are detailed in PNNL (1997) and PNL-MA-580, Rev. 2.

Analytical Methods. Analytical methods are selected to meet the minimum goal of detecting levels equivalent to a dose of 1 mrem if that concentration were sustained for a year. An additional goal is to achieve the lower detection levels available using standard state-of-the-art analytical methods. These goals are summarized in the Laboratory Procedures subsection. In some cases, special techniques have been developed and are used to measure specific contaminants known to be discharged into the surface waters. Analytical methods and detection limits are summarized in the Laboratory Procedures subsection.

Riverbank Springs

Routine riverbank spring sample locations were given in Figure III.A-4. Samples are collected annually along the shoreline of the 100-B,C Area, 100-K Area, 100-N Area, 100-D Area, 100-H Area, 100-F Area, downstream of the Old Hanford Townsite, and at the 300 Area. Groundwater enters the Columbia River at these locations, with contaminant levels significantly higher than background.

Water samples collected at these locations are analyzed for those constituents known or suspected to be present in the local groundwater. The primary radionuclides of concern include tritium, uranium, ^{60}Co, ^{90}Sr, ^{99}Tc, and ^{129}I. Chemical contaminants of concern include metals (primarily chromium), volatile organic compounds, and anions.

Samples are typically collected using a siphon pump directly in an improved discharge zone to avoid agitation of the sediments. The sampling zone of the riverbank spring is improved by scooping the sediment away from the discharge area and allowing the disturbed sediments to settle before the siphon pump is used. Riverbank spring samples are handled and transported in a manner similar to the river-water samples discussed above.

Onsite Ponds

Sampling Locations. Three onsite ponds (see Figure III.A-4), located near operating areas, are routinely sampled. B Pond, located near the 200-East Area, was excavated in the mid-1950s for disposal of process cooling water and other liquid wastes occasionally containing low levels of radionuclides. West Lake, located north of the 200-East Area, is recharged from groundwater (ARH-CD-775). This lake has not received direct effluent discharges from site facilities, and radionuclide concentrations are influenced by the local groundwater. The Fast Flux Test Facility Pond, located near the 400 Area, was excavated in 1978 for the disposal of water from various facilities in the 400 Area. The volume of water present in all of the onsite ponds has been decreased significantly during recent years as a result of changes in liquid effluent-disposal practices. In addition, site plans call for the elimination of discharges of liquid effluents to the ground in the near future. As such, sampling of these ponds is becoming more difficult with time and the need for continued monitoring may be diminished, if not eliminated.

Fluor Daniel Hanford, Inc. (and its enterprise companies) is responsible for monitoring effluents discharged to the ponds and for operational surveillance of the ponds (HNF-EP-0573-5).

Sample Collection and Analysis. Grab samples (10 L) are collected quarterly from each pond. Care is taken to avoid surface debris and resuspension and inadvertent collection of bottom sediments. Unfiltered aliquots of the samples are analyzed for gross alpha and gross beta activities, gamma-emitting radionuclides, tritium, ^{90}Sr, and ^{99}Tc according to the current sampling schedule (e.g., PNNL-11464).

Offsite Irrigation Water

Samples are collected from an irrigation canal that obtains water from the Columbia River downstream of the Hanford Site (see Figure III.A-4). Consumption of food irrigated with Columbia River water from downstream of the site was identified as a pathway contributing to the potential dose to the hypothetical maximally exposed individual in 1996 (PNNL-11472).

The Riverview Irrigation Canal is sampled and analyzed for total alpha, total beta, gamma emitters, tritium, ^{90}Sr, ^{234}U, ^{235}U, and ^{238}U according to the current sampling schedule (e.g., PNNL-11464). Strontium-90 is the primary radionuclide of concern because it was identified as one of the primary contributors to the calculated hypothetical dose to the public via the water pathway (PNL-6464).

Quality Control Methods

Surface-water surveillance is controlled under the overall project quality assurance and analytical control program described in the subsection entitled Quality Assurance and Quality Control.

Reporting/Alarm Levels

Anomalous results are flagged by computer screening of reported data as they are entered into the project database. Levels for reporting to DOE-RL have been established and are listed in the Records Management and Reporting subsection. Reporting levels are equivalent to the concentration that might lead to a dose of 1 mrem EDE to the maximally exposed individual if it were sustained for a year. This reporting level provides early indication of conditions that might eventually require reporting to DOE-HQ as required by DOE Order 5400.5.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Sediment Surveillance

As a result of Hanford Site operations, large quantities of radioactive materials were discharged to the Columbia River. On release to the river, the radioactive materials were dispersed rapidly, sorbed onto inorganic particles and detritus, incorporated into aquatic biota, and deposited on the riverbed as sediment. Fluctuations in the river-flow rate, as a result of the operation of hydroelectric dams, annual spring freshets, and occasional floods, have resulted in the resuspension, relocation, and redeposition of the contaminated sediments.

Since the shutdown of the original single-pass cooling reactors, the radionuclide burden in the river-surface sediments has been decreasing as a result of radioactive decay and subsequent deposition of uncontaminated material. However, discharges of some radionuclides to the Columbia River still occur through the seepage of contaminated groundwater into the river. It is expected that some of these radionuclides are either deposited directly or sorbed onto the sediment materials and deposited on the river bottom.

The accumulation of radioactive materials in sediment can lead to exposure of humans through ingestion of aquatic species, through sediment resuspension into drinking water supplies, or as an external radiation source irradiating people fishing, wading, sunbathing, or participating in other recreational activities associated with the river and shoreline.

Public exposures are well below the level at which routine surveillance of the sediments is required (DOE/EH-0173T). However, periodic sampling is necessary to confirm the low levels and to ensure that no significant changes have occurred over time that may increase the potential exposure to the public through this pathway.

Sampling on a routine basis is necessary to meet site-specific surveillance requirements (DOE/EH-0173T). It is imperative that the whereabouts and fate of the contaminants known to enter the river along the Hanford Reach be understood. Because the source of radionuclides entering the river is predominantly the seepage of contaminated groundwater, sampling of the sediments and river water near the discharge zones provides an indication of the levels entering the river and also confirms findings of the Groundwater Monitoring Project conducted at the Hanford Site.

Public concern about the levels of contamination in the river sediments and the potential for these contaminants to be resuspended and relocated, perhaps in areas of public use, is evident in the Hanford Site area. Routine sampling of the sediment material provides the public a degree of assurance that both the potential problem (resuspension and redistribution of contaminated sediment) and their concerns are being considered and addressed appropriately.

Objectives

The objectives of the sediment-surveillance activities, consistent with overall surface environmental surveillance, include the following:

- verify that doses caused by Hanford Site operations through this pathway remain low, by means of periodic river-system evaluation, sampling, and analysis

- provide an indication of changes in environmental conditions with potential for increases in public exposures

- provide public assurance in the credibility of site surveillance and that the radiological conditions and potential exposure pathways are understood and receive appropriate attention.

Plan Rationale and Criteria

The basis for sampling sediments from surface waters is discussed in DOE/EH-0173T. In addition, other environmental monitoring guides and references have been considered in the development of the sediment-sampling plan. The locations, sampling frequency, and analyses performed routinely on sediment samples are summarized annually (e.g., PNNL-11464). Additional rationale and specific criteria are described below.

Media Selection

Sediments along the Hanford Reach are known to contain elevated concentrations of radionuclides and produce higher-than-normal levels of external radiation. Contaminants in sediments may lead to public exposure through the ingestion of aquatic species, through sediment resuspension into drinking water systems, and as an external radiation source. Sediment sampling and the measurement of external radiation emanating from the sediments provide indications of the potential for human exposure from this pathway. Sediments are sometimes more sensitive indicators of waterborne contaminants than water or aquatic biota because some contaminants may accumulate in sediments.

All sediment samples are collected in accordance with documented, reviewed, and approved collection procedures contained in PNL-MA-580, Rev. 2. Analytical methods are summarized in the subsection entitled Laboratory Procedures.

Analyte Selection

Sediment samples are analyzed for contaminants known or suspected to be present as a result of past or current operations at the Hanford Site. Effluent discharge reports are reviewed to identify contaminants currently entering the river. Groundwater-monitoring reports identify those contaminants near the river and potentially entering the river that must be considered in the sampling plan. Historic reports, documenting past releases or sediment-contaminant concentrations, are reviewed to determine contaminants of concern as a result of past operations.

Sediment samples are routinely analyzed for gamma-emitting radionuclides (gamma scan), ^{90}Sr, ^{235}U, ^{238}U, ^{238}Pu, and ^{239,240}Pu, according to the current sampling schedule (e.g., PNNL-11464). Such analyses are consistent with past and current releases and historical data relative to contaminants in the sediments. In addition, sediment samples are routinely analyzed for metals.

Sampling Frequency

Sampling of sediments is conducted on an annual basis. This is deemed satisfactory because the sediments are not in a critical exposure pathway to the public. Sampling is conducted consistent with spring freshets (i.e., sampling occurs after the spring high water to provide a consistent and more easily interpreted information base).

Core samples, to determine the fate and buildup of contaminants in the sediment over time, may be collected periodically, commensurate with findings of past core-sampling activities and in consideration of future activities that may resuspend and redistribute the sediment.

Sampling Location Selection

Samples of Columbia River sediment are collected at the locations shown in Figure III.A-5. Samples are collected upstream of the Hanford Site (beyond the influence of Hanford Site facilities) behind Priest Rapids Dam. Samples are collected downstream of the Hanford Site at Richland and behind McNary Dam (the nearest downstream impoundment). Four samples are collected behind each of the dams at approximately equal distances along a sample transect. This provides additional information relative to the distribution of contaminants in the sediments across the river. In addition, samples are collected along the Hanford Reach, at locations nearer the discharges (past and current), in areas where material is known to be deposited, and in areas commonly used by the public. These locations include the White Bluffs, 100-F, and Hanford Sloughs.

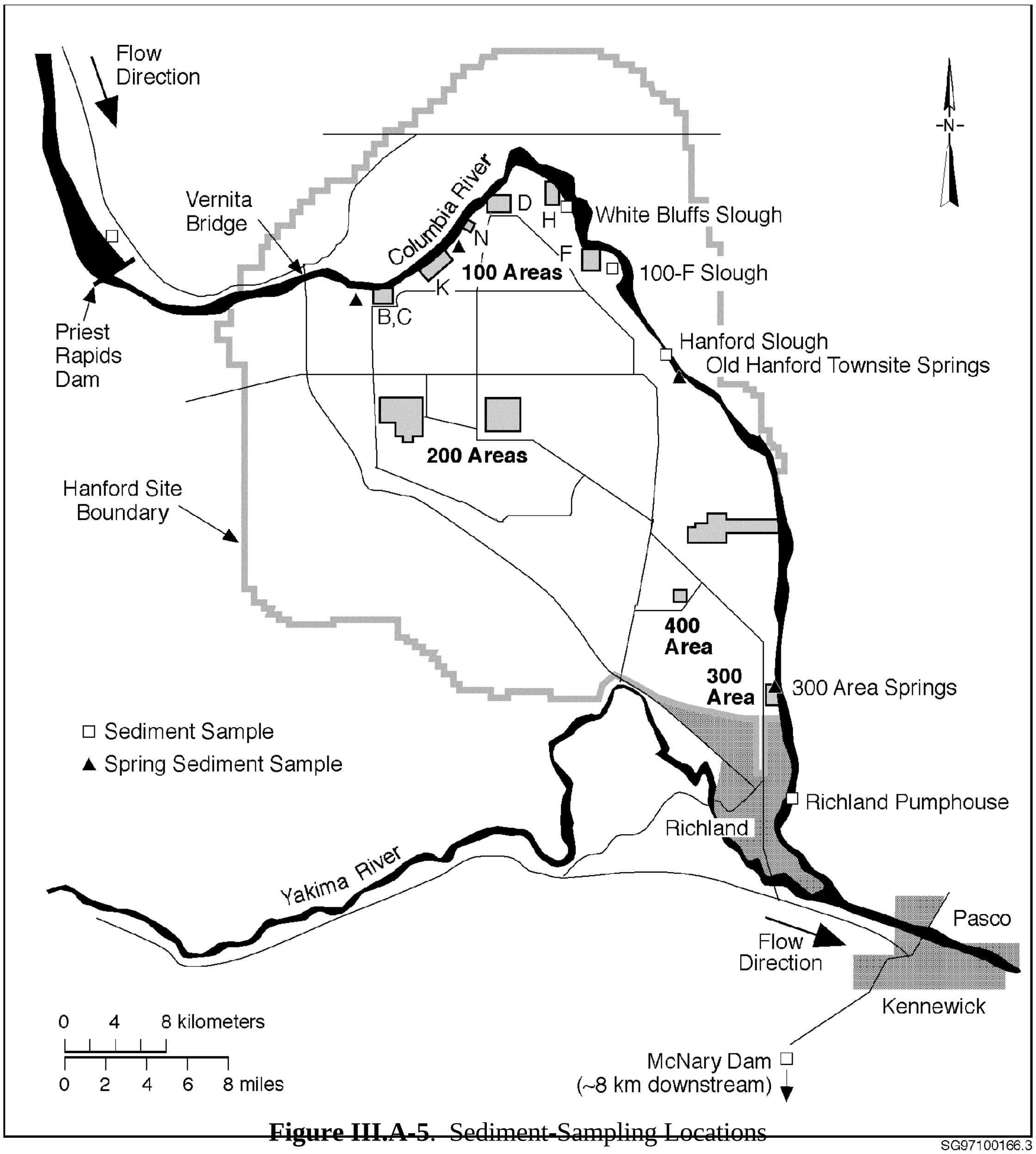

Figure III.A-5. Sediment-Sampling Locations

In addition to the routine sediment-sampling activities, core samples are collected periodically from the upstream and downstream impoundments to determine the distribution and fate of the contaminants present as a result of past Hanford Site operations. The frequency of this sampling is dependent on the findings of past sampling activities and in consideration of future river and/or downstream impoundment activities.

Sample-Collection Methods

Because of the depth and swiftness of the river at some of the sediment-sampling locations, samples are collected using a dredge-type mechanical sampler. In some cases, primarily in the shallow-water sloughs along the Hanford Reach, the dredge is used manually to better control the sample depth. Samples are collected according to PNL MA-580, Rev. 2.

Analytical Methods

Analytical methods are selected to meet the minimum goal of detecting levels equivalent to a human dose of 1 mrem EDE if that concentration were sustained for a year. An additional goal is to achieve the lower detection levels available using standard state-of-the-art analytical methods. These goals and the analysis methods and detection limits are summarized in the subsection entitiled Laboratory Procedures.

Quality Control Methods

Sediment surveillance is controlled under the overall project quality assurance and analytical control program, described in the Quality Assurance and Quality Control subsection.

Reporting/Alarm Levels

Anomalous results are flagged by computer screening of reported data as they are entered into the project database. Levels for reporting to DOE-RL have been established and are listed in the Records Management and Reporting subsection. Reporting levels are equivalent to the concentration that might lead to a dose of 1 mrem EDE to the maximally exposed individual if it were sustained for a year. This reporting level provides early indication of conditions that might eventually require reporting to DOE-HQ as specified by DOE Order 5400.5.

Exceptions

No exceptions have been taken to should* statements in DOE/EH-0173T.

Biota and Soil Surveillance

This subsection details the former tasks of agricultural products, vegetation and soil, and fish and wildlife. Surveillance of these media provides the baseline data to address and evaluate the occurrence of both onsite and offsite radiation contamination.

A master schedule for all routine sampling is published annually (e.g., PNNL-11464). The resulting analytical data are reviewed individually and collectively, summarized, and published in the annual environmental monitoring report (e.g., PNNL-11472). That report compares the trends in the monitoring data collected over the previous 5 yr, and the information is used to reevaluate sample-site selection, media to be sampled, and radionuclides that require monitoring.

The data collected from the biota and soil surveillance activities are maintained in the Hanford Environmental Information System (HEIS), a comprehensive computer database that allows comparisons with previously collected data from the same location or from designated control sites. Maintenance of these data is important as long as accident scenarios indicate the potential for significant offsite contamination.

The biota and soil surveillance activities are outlined below.

- Agricultural products are major contributors to the economy of the Columbia Basin. The Hanford Site is surrounded by large tracts of arable land, and surveillance of agricultural products grown on this land is an important element of surface environmental surveillance. Radioactivity of Hanford Site origin can reach agricultural areas by two pathways: atmospheric dispersion and application of irrigation water from the Columbia River. The Riverview area of Pasco is serviced by the Franklin County Irrigation District and the area north of Richland, designated the Horn Rapids area, is serviced by the Port of Benton pump station. Both facilities provide irrigation water that is removed from the Columbia River immediately downstream of the Hanford Site. Agricultural products are grown in downwind areas around the site perimeter and can be potentially affected by atmospheric deposition.

  In most cases, current levels of key radionuclides are at or below analytical detection limits. Assurance that regional agricultural products are not contaminated is important to the public, the region's agribusinesses, and the DOE. Therefore, periodic sampling must be done in a manner and frequency that provide the ability to estimate the contribution from site operations.

- Soils and vegetation at publicly accessible areas near and downwind of the site must be monitored to provide assurance to the DOE and the public that these media are not significantly contaminated by Hanford-originated emissions. Surveillance of soils and vegetation is designed to monitor atmospheric deposition of contaminants at offsite locations not influenced by agriculture and at onsite locations adjacent to potential sources of environmental radioactivity. Atmospheric data and modeling indicate that Hanford Site effluents can be carried offsite and deposited onto the land, where there is then the potential for accumulation. Airborne radioactive materials can be either gaseous or particulate and can originate from operational facilities or from resuspension of contaminated soil by wind.

  Soils and vegetation on portions of the Columbia River shoreline bordering the Hanford Site are also monitored because they may be exposed to contaminants present in Hanford Site groundwater. Data collected from these media samples are used to maintain continuity in the environmental database in support of any possible emergency response, to compare to historical data, to evaluate trends, and to provide reassurance to the public that Hanford Site effluents do not pose a threat to public health. In many cases, there is little difference between onsite and offsite concentrations at upwind or downwind locations; however, some samples collected near onsite operational areas may have slightly elevated concentrations.

- Fish and wildlife on and off the site are valued natural and recreational resources. Fish in the Columbia River and game that cross the river or found on islands in the Hanford Reach may be harvested by the public for consumption. It is important, therefore, that fish and wildlife be sampled to document levels of radioactivity in the edible tissues. Hanford Site fish and wildlife may be exposed to radioactive materials from a number of sources. Fish and other aquatic life may be exposed to low levels of radionuclides present in Hanford Site groundwater entering the Columbia River via shoreline springs (i.e., 100-N Area, Old Hanford Townsite, and 300 Area). Exposure to Hanford Site effluents, unplanned releases, and releases from cleanup activities may also lead to low-level contamination of edible tissues.

  A large inventory of radioactive waste is found in the 100, 200, 300, and 600 Areas, and there is a potential at some of these sites for biointrusion. The collection of species with small home ranges adjacent to operating areas assists in the verification of facility controls. Most waste ponds onsite have been decommissioned and no longer provide a significant habitat for ducks.

  Because of the potential for exposure to contaminants and the offsite migration of some animals, continued annual surveillance is considered necessary to provide reassurance to the hunting and fishing public.

  Background samples are collected from distant locations, so that the contribution of Hanford-related radionuclides in wildlife tissues can be determined.

Objectives

The objectives of the biota and soil surveillance activities are the following:

- verify that doses (through the agricultural products pathway and consumption of edible fish and wildlife) caused by Hanford Site operations remain low and quantifiable through periodic sampling as required by DOE/EH-0173T

- provide assurance to producers and consumers of agricultural products that the degree of contamination caused by site operations is known and documented in the annual Hanford Site environmental report (e.g., PNNL-11472) and special reports as required

- provide baseline data to quantify any incremental effects of unexpected releases of radionuclides and long-term buildup of radionuclides in biota and soil

- monitor the buildup and inventory of long-lived radionuclides onsite and offsite from deposition of aqueous and airborne releases

- monitor contaminated, or potentially contaminated, areas along the Columbia River shoreline

- provide assurance to the public that the degree of contamination from Hanford Site operations is known and quantified

- evaluate radionuclides in wildlife near operational areas as indicators of biointrusion or inadvertent exposure.

Plan Rationale and Criteria

The surveillance criteria for biota and soil are based on *should** statements found in DOE/EH-0173T. Pathway analyses indicate that effluents of Hanford origin can reach agricultural products through atmospheric deposition at downwind locations and through irrigation with contaminated Columbia River water. Specific agricultural pathways target a variety of local, representative products identified in DOE/EH-0173T and emphasize the concern for public assurance.

Soil and vegetation sampling supports air-monitoring efforts to document fugitive radioactive effluents that settle on the ground. Additionally, special sampling is conducted as needed to address site-cleanup actions, decommissioning, and transfer of property to other federal, state, or local agencies. This approach is consistent with guidance given in DOE/EH-0173T.

Vegetation sampling has been reduced in recent years because environmental concentrations of routinely monitored radionuclides have fallen below detection limits. Consequently, monitoring has been focused on those onsite locations that have indicated potentially elevated concentrations, on perimeter downwind locations, and on an upwind location. Special onsite vegetation sampling will emphasize sample collection along the Columbia River shoreline, aquatic vegetation in the river, and selected terrestrial location sites associated with cleanup activities.

Fish and wildlife sampling is based on the potential for consumption by hunters or fishers, the likelihood of exposure, and the possibility of accumulation of radionuclides by fish and wildlife. The species of fish and wildlife selected for sampling are found in sufficient abundance that sampling will not affect population stability. Species that may possibly be consumed as harvestable fish or wildlife are preferred; however, consideration is also given to species that have a high potential for exposure to site effluents or that may intrude into waste sites. Consideration is also given to species that may be specifically consumed by ethnic groups.

Sampling procedures are designed to ensure that sample collection is performed in an unbiased manner. Sampling and data quality objectives are continuously reviewed, as are scheduling or media substitutions depending on availability of farm products and current interests and issues regarding agribusiness and site activities. The data from these samples are also used to support offsite dose estimates based on effluent monitoring.

Media Selection

Selection of specific media is based on their significance to human dose. Specific agricultural products are selected because they are potentially exposed to atmospheric deposition, irrigation with Columbia River water containing Hanford Site effluents, or naturally contaminated groundwater; consumed by farmers; sold commercially; or are known to contribute to a human dose through a specific pathway. The media that are routinely monitored include the following:

- milk - Whole raw milk is collected from control locations (generally upwind and distant from the Hanford Site) and from dairies closer and downwind of the site.

- farm produce - Surveillance of farm produce involves the collection of 10 samples distributed among fruit (apples, grapes, cherries), vegetables (potatoes), and leafy vegetables. Specific foodstuffs are collected by area (Figure III.A-6), and not all areas yield the same types of produce.

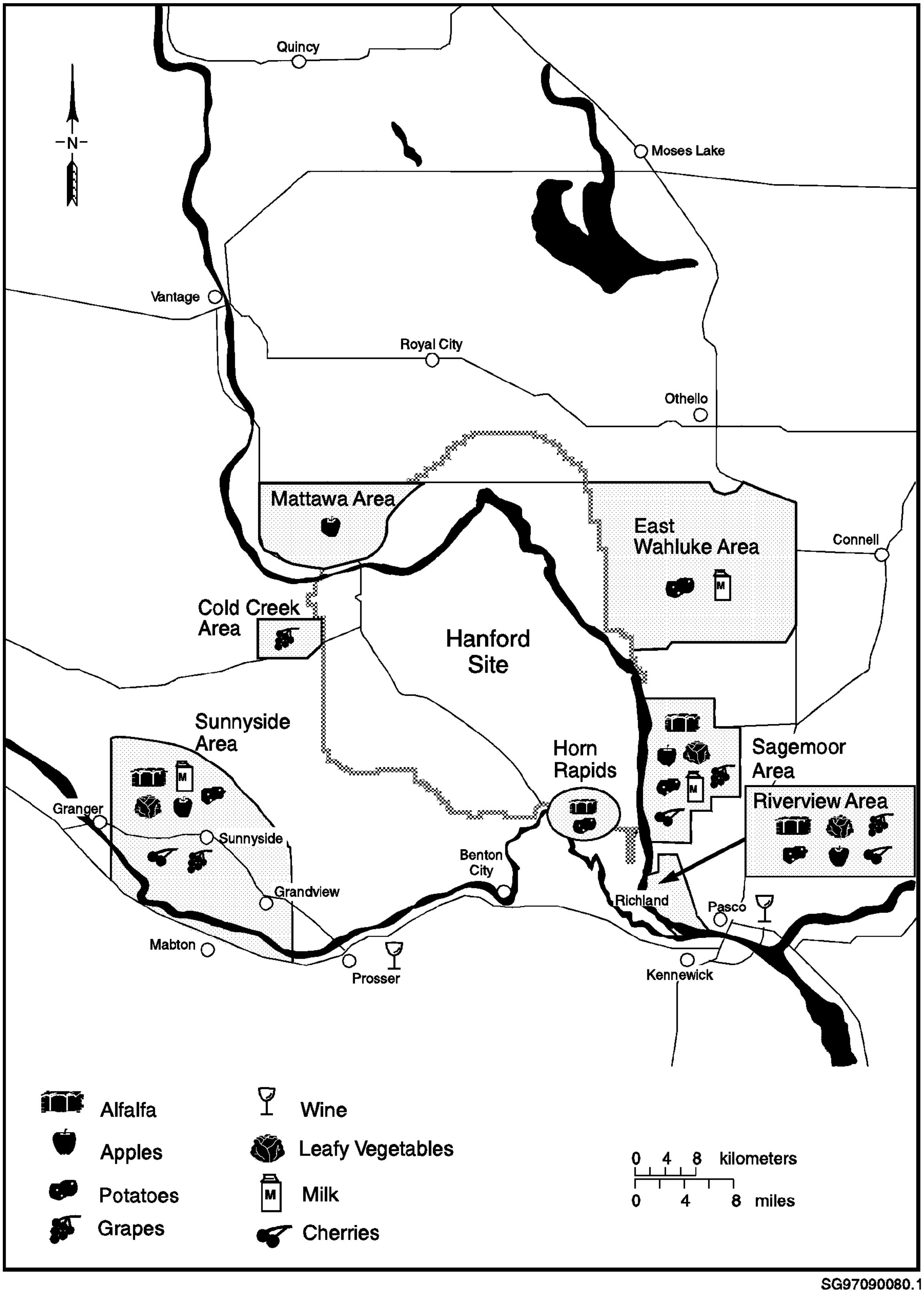

Figure III.A-6. Food- and Farm Product-Sampling Locations

- alfalfa - Alfalfa samples are collected from one upwind control location and three locations adjacent to the Hanford Site.

- wine - Red and white varieties of wine are collected from upwind and downwind locations. Only wines that have been prepared from grapes grown in the designated sampling areas are analyzed.

- soil and vegetation - Soil samples consist of cores taken to a depth of 2.5 cm. Vegetation is removed before coring, and the sample is sieved before analysis at the analytical laboratory. Routine vegetation samples consist of the prevalent natural plants, usually rabbit brush and sagebrush, at the sampling locations.

- fish - Whitefish have historically been sampled because of their propensity to accumulate radionuclides; however, carp and bass are also sampled. Two sample types are obtained: fillet, representing the edible portion; and offal, the eviscerated remnants including the head, skin, fins, and bones.

- game - The species collected include deer, rabbits, geese, and upland game birds (usually pheasants, but may include chukars). Resident Canada geese are sampled from the Columbia River. Muscle and bone samples are collected.

Analyte Selection

Radionuclides are selected based on monitored effluent releases, degree to which the radionuclide contributes to the dose associated with the pathway, and public and agribusiness concerns (DOE/EH-0173T). Cleanup and other site activities that occur in the future may require analyses for specific radionuclides in biota and soil. These will be addressed on a case-by-case basis as they occur. Analytes routinely monitored for in specific media are given in the master sampling schedule (e.g., PNNL-11464).

Agricultural products are analyzed for tritium, ^{90}Sr, ^{129}I, and gamma emitters (including ^{137}Cs). These radionuclides are important because of their biological activity: ^{129}I concentrates in the thyroid via the milk pathway, ^{137}Cs is found in muscle, ^{90}Sr accumulates in bone and alfalfa (compared to other crops), and tritium is usually incorporated into liquids within meat or plant material as tritiated water. Principal radionuclides associated with atmospheric fallout are monitored to partition Hanford-related impacts from background and fallout. Generally, fallout radionuclides include ^{90}Sr and ^{137}Cs. Last, radionuclides must have a sufficiently long half-life to pose a realistic hazard by the food-chain pathway.

Soil samples are analyzed for the radionuclides common to Hanford Site operations: gamma emitters, ^{90}Sr, ^{235}U, ^{238}U, ^{239,240}Pu, and, for selected samples, ^{241}Am. Vegetation samples are analyzed for gamma emitters, uranium, ^{90}Sr, and ^{239,240}Pu. These radionuclides are selected because they persist in the environment, given their long half-lives, and because they are indicative of past site operations.

Fish and wildlife samples are analyzed for ^{90}Sr and ^{137}Cs. Gamma spectrometry, which is used to measure ^{137}Cs, also measures ^{7}Be, ^{40}K, ^{60}Co, ^{125}Sb, ^{152}Eu, ^{154}Eu, ^{155}Eu, and ^{134}Cs. Radionuclide concentrations in wildlife during the past 10 yr have indicated little need to conduct routine analyses for other radionuclides.

Sampling Frequency

Agricultural products are collected during the harvest season. Sampling locations that represent the potential for the highest environmental dose from Hanford Site effluents are sampled more frequently than others. Specific fruits and vegetables are sampled in alternating years or on a 3-yr cycle as indicated in the master sampling schedule (e.g., PNNL-11464). Approximately 20 milk samples are collected from several locations on a quarterly or semiannual basis.

Soil and vegetation samples have been collected on a 5-yr cycle since 1994, and are scheduled for collection in 1999. The sampling program will be reevaluated/adjusted to reflect current conditions and data quality objectives in 1999. This cycle is adequate to detect long-term trends in environmental radioactivity. This sampling schedule is consistent with DOE/EH-0173T requirements and the change in the site's mission from production to cleanup.

Fish and wildlife are collected on a rotating schedule, as indicated in the master sampling schedule (e.g., PNNL-11464). This schedule exceeds the minimum requirements of DOE/EH-0173T; however, the current level of effort is consistent with meeting DOE concerns for public reassurance relative to contamination levels in fish and game in the region, emphasis on cleanup activities on the site, and recent concerns about contaminants in the Columbia River.

Fish collections have been placed on a 2- to 3-yr rotating schedule, including collections at background locations. Whitefish and carp are collected in alternating years from Hanford Reach locations (in particular, the 100-N to 100-D section of the river) and at background locations every 5 yr. The more frequent collection of carp and whitefish is justified because both species are bottom-feeding omnivores and are prone to accumulate radionuclides associated with benthic food chains. Bottom-feeding fish generally accumulate higher levels of contaminants than do species with other feeding preferences. Bass are sampled from the 100-F and Hanford Sloughs every 3 yr because of their popularity with local fishers.

Wildlife samples are collected in alternating years, with rabbits alternating with deer and pheasants alternating with geese. Wildlife populations undergo natural fluctuations, and routinely scheduled species are not always abundant or easily collected. When this occurs, the sampling and data quality objectives are reviewed and scheduling or species substitutions are considered. Offsite control wildlife are collected on a 5-yr schedule. All collections of fish and wildlife are conducted under permit with the State of Washington Department of Wildlife, the U.S. Fish and Wildlife Service, and PNNL's animal care committee, which oversees all PNNL activities dealing with vertebrate animals.

Sampling Location Selection

Locations are selected to provide samples that are likely to contain the maximum offsite concentrations of radionuclides from Hanford Site-originated atmospheric and liquid effluents (see DOE/EH-0173T). Control or background locations are upwind of the Hanford Site or are independent of the Hanford Reach and Hanford Site groundwater.

The Riverview area and the Horn Rapids area are sampled for farm products because they are the first agricultural areas located downstream of the Hanford Site that use Columbia River water for irrigation. The remaining agricultural sites are located primarily on the site perimeter in downwind locations (see Figure III.A-6).

Sites for soil and vegetation sampling are located in undisturbed areas to facilitate monitoring of long-term accumulation (Figure III.A-7). Generally, soil and vegetation samples are collected near air- and external radiation-sampling locations to facilitate interpretation of results (see DOE/ET-0173T). Sampling locations along the Columbia River shoreline are selected to monitor potential public exposures to contaminated vegetation. Onsite soil- and vegetation-sample locations are selected to provide close-in monitoring of operational areas that can release radioactive materials.

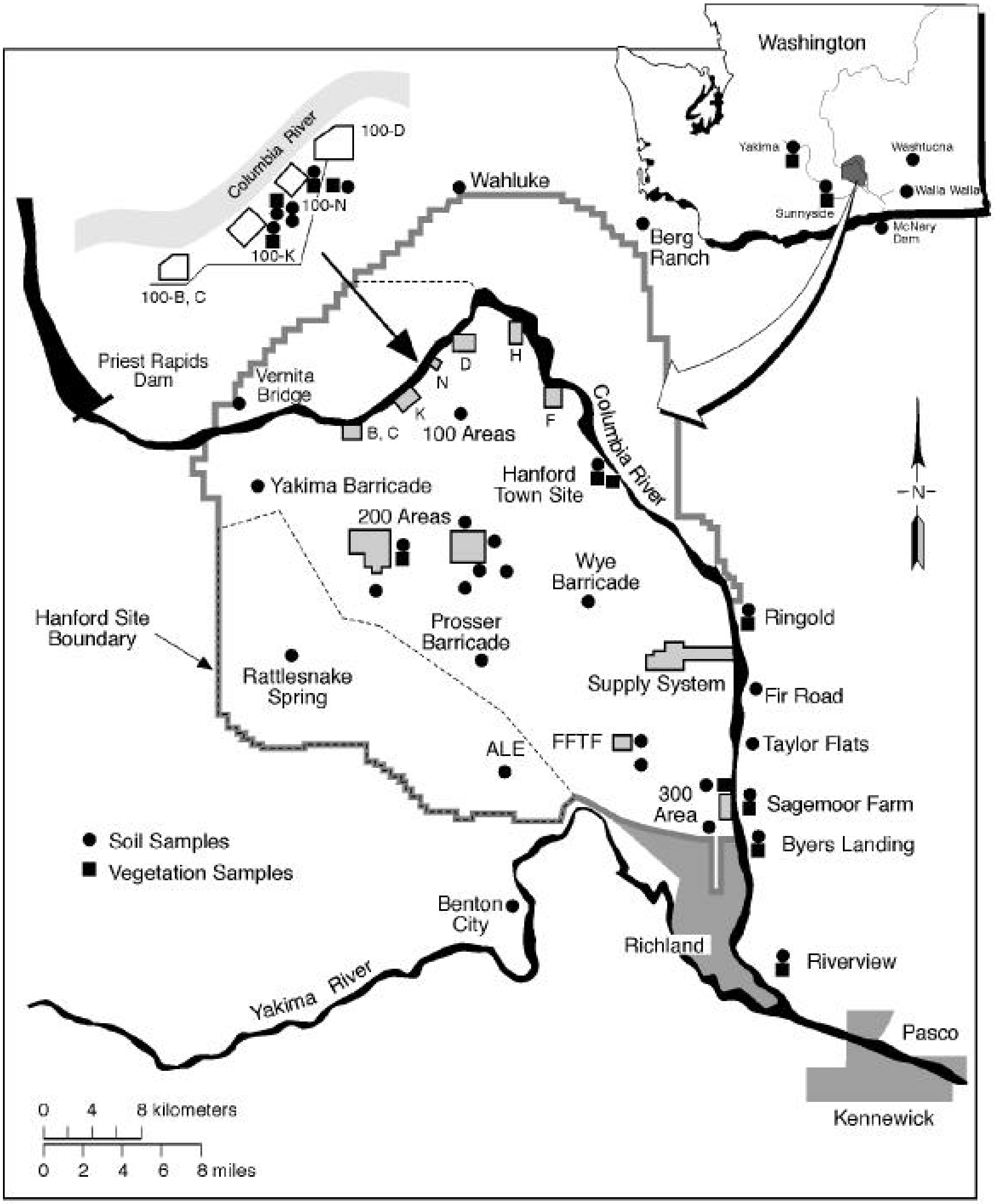

Figure III.A-7. Soil- and Vegetation-Sampling Locations

Samples of fish are collected immediately adjacent to and downstream of locations where potentially contaminated spring water is known to enter the Columbia River (Figure III.A-8). Wildlife are collected from locations with the highest potential exposure to Hanford Site radioactive effluents (e.g., the 100-N Area springs). Special nonroutine analyses are anticipated for elk on the Hanford Site because the population has moved onto the central plateau and toward the Columbia River.

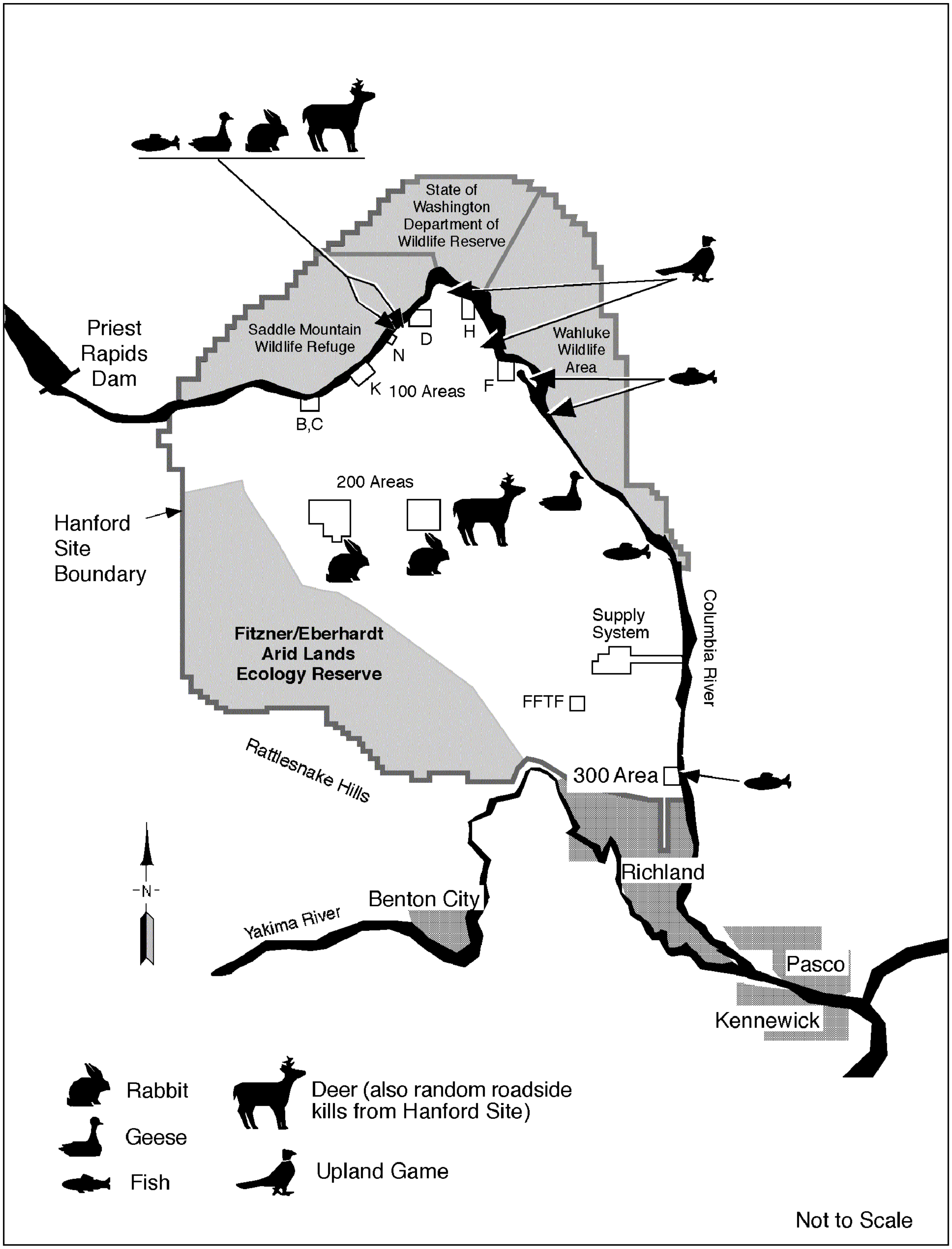

Figure III.A-8. Wildlife-Sampling Locations, Excluding Background Area

Control samples are collected from areas expected to receive approximately the same contribution of fallout radioactivity as is found on the Hanford Site. For fish, these controls are distant upstream residents that have a low probability of passing over upstream dams. Control sites for game species are distant, generally considered upwind of Hanford (e.g., Boardman, Oregon, for rabbits and remote arid locations for deer).

Sampling or Measurement Methods

Sampling methods are described in PNL-MA-580, Rev. 2, which also addresses sample preparation. Agricultural products are collected in a manner to ensure that adequate amounts of sample are obtained to meet analytical detection limits. Care is taken to ensure that the produce sample is not contaminated with soil.

Soil is sampled to a depth of 2.5 cm and a diameter of 10 cm with a shallow coring device ("cookie cutter") and composited to form one sample from five cores. Vegetation samples consist of the current year's growth collected from shrub species present in proportion to their estimated abundance at the sample site.

Fish and wildlife are collected by trapping, hunting, and several methods of fishing, including rod and reel, electroshocking, and seining. Disposal of animal waste is performed in accordance with state regulatory agency and PNNL waste-management guidance.

Sample-Handling/-Treatment Methods

Perishable agricultural samples, such as milk, are stored in ice chests when collected and during transport to the analytical laboratory (see PNL-MA-580, Rev. 2). Usually, samples are delivered to the analytical laboratory on the day of collection. If they must be stored before delivery, they are refrigerated or frozen as needed to minimize spoilage.

Soil and vegetation samples are double bagged when collected to minimize the potential for cross-contamination. Some soil samples are taken with a "riffle splitter," producing two homogeneous subsamples that are sent to different analytical laboratories as part of a cooperative sampling program with the State of Washington Department of Health.

Samples of fish and wildlife are processed to obtain bone and edible tissue. Special care is taken to ensure that flesh and organs are not contaminated by the skin or hair or by piercing the gastrointestinal tract when cleaning the animal. Whenever possible, a sample mass adequate to meet the minimum detectable concentration is collected; however, at times, sample masses are less than the required amount and the minimum detectable concentration increases proportionally. Tissue samples must also be kept free of dirt because background levels in the soil can lead to erroneously high values.

Analytical Methods

Analytical methods are selected to meet the minimum goal of detecting a radionuclide concentration that would yield a dose of 1 mrem EDE if that concentration were sustained in the medium and the medium were consumed for a year. An additional goal is to achieve the lower detection levels available using standard state-of-the-art analytical methods. These goals and the analysis methods are discussed in the subsection entitled Laboratory Procedures.

Quality Control Methods

Surveillance of biota and soil is controlled under the overall project quality assurance and analytical control program described in the Quality Assurance and Quality Control subsection. Duplicate samples of selected farm products are sent to the State of Washington Department of Health and/or the U.S. Food and Drug Administration for comparative analysis.

Reporting/Alarm Levels

Anomalous analytical results are flagged by computer screening as data are entered into the HEIS database. Concentrations requiring DOE-RL notification have been established and are listed in the subsection entitled Records Management and Reporting. Reporting levels are equivalent to the concentration that might lead to a dose of 1 mrem EDE to the maximally exposed individual if it were sustained for a year. For consumable media, this is a function of the concentration in the edible portion of the medium. For soil, it is external exposure, with the exceptions of ^{90}Sr and ^{137}Cs. Reporting levels for these radionuclides are nominally equivalent to a dose of 10 mrem if sustained for 1 yr because the large natural variability in such samples makes it impractical to detect a 1-mrem difference. This reporting level provides early indication of conditions that might require reporting to DOE-HQ as required by DOE Order 5400.5.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

External Radiation Surveillance

External radiation exposure can be produced by various sources on and around the Hanford Site. The environmental pathways through air and surface water can transport radionuclides from effluent sources (point or diffuse) to locations near the public and other biota. Many of these released radionuclides produce penetrating particles and photons (i.e., beta and gamma radiations) during decay processes in media external to an organism. These media include cloud passage, surface water, soil, sediment, and vegetation. Other actual or potential sources of external radiation on the Hanford Site include radioactive waste-handling, -storage, and -processing activities and radiation-generating facilities and equipment.

Several actual or potential sources could lead to external radiation exposure of the public or onsite biota from radiation or radioactive materials. These sources include waste-process streams, waste sites, diffuse sources, and onsite transport of sources or wastes. Various radiological emergency scenarios may result in significant levels of external radiation in the environment. Because of continuing changes in site operations, and land use, the significance of each of these pathways continues to vary.

Each year, a radiological pathway analysis and exposure assessment is performed. The pathway analysis, based on effluent data, does not address existing and potential external radiation from sources such as contaminated surface sediments, soil, and waste sites. However, background and elevated levels of external radiation have been studied extensively in the Hanford Site environment (PNL-3127, PNL-7124, PNL-8789), with detection of measurable increases caused by Hanford Site operations at various onsite locations and on the Hanford Reach of the Columbia River. An aerial survey (EGG 10617-1062) confirmed most of these findings, indicating several onsite locations and locations along the Hanford Reach that have above-background gamma levels. These elevated terrestrial exposure locations are mainly to the south and west of the Columbia River (onsite operational areas) and are generally not accessible to the public for extended periods of time. The elevated radiation locations along the river, islands, and state/federal wildlife land of the Hanford Site are areas with access restrictions; however, the public occasionally occupies these areas for varying lengths of time. The highest exposure rate at a publicly accessible location occurs near the 100-N Area shoreline. At this location, exposure levels are approximately twice the natural terrestrial background for the area. These studies and other data indicate that Hanford operations, in recent history, have not caused detectable increased levels of offsite external radiation.

Generally, it can be expected that slight increases in offsite external exposure rates from current routine releases will be difficult if not impossible to detect above background using cost-effective conventional monitoring (thermoluminescent dosimeters [TLDs], survey meters, etc.).

Objectives

The objectives of external radiation monitoring are the following:

- obtain external exposure measurements for actual and potential external radiation levels at locations of actual and potential public access to support the verification that doses to the public through all potential pathways from Hanford Site operations remain low relative to standards

- provide confirmatory measurements of actual or potential increases in exposures of the public or biota to radiation or radioactive materials from nuclear operations, waste-process streams, waste sites, diffuse sources, or onsite transport of sources or waste

- obtain preoperational baseline data and environmental data near waste units scheduled for treatment and/or restoration to assess the integrated effects of individual operations

- obtain measurements at the site perimeter and in nearby communities to provide public assurance that the degree of external radiation exposure from site operations is known

- measure onsite and offsite external radiation exposure for emergency response to accidents and provide measurements to assess the environmental effects and doses from unusual releases

- support the evaluation of the effectiveness of Hanford Site effluent controls and models for predicting the concentrations of pollutants in the environment

- conduct surveillance to meet Fast Flux Test Facility technical specifications (HEDL 1981).

Plan Rationale and Criteria

The criteria for external radiation monitoring consist of those identified as the *should** statements in DOE/EH-0173T. Any exceptions to those criteria are identified in the Exceptions discussion below. The level of surveillance and the specific criteria to meet the above objectives are described below.

The monitoring locations, measurements, methods, and frequencies for meeting external radiation surveillance objectives and criteria are given each year in the sampling schedule published for that year (e.g., PNNL-11464). The rationale and any specific criteria for these selections are discussed below.

Media Selection

External radiation exposures are measured with consideration for the types and levels of exposure expected from the various pathway transport media and other direct radiation sources. Some of the critical environmental media or sources causing potential external radiation exposure are airborne cloud passage, immersion in surface water, vegetation (i.e., contaminated tumbleweeds), shoreline sediments, and facilities at waste-handling sites.

Most of the types of radiation causing external exposures are gamma photons and beta particles. External neutron and alpha particle exposures to the public have negligible potential. Historical data support the approach of designing the measurement methods mainly for photon sources, but pure beta emitters exist in the environment unaccompanied by gamma emitters (e.g., ^{90}Sr). Exposure levels at publicly accessible locations are typically in a range from the natural background level to possibly two to three times greater than the natural terrestrial background.

Analyte Selection

Whole-body and skin doses from external radiation fields caused by gamma (i.e., ^{137}Cs) and “hard” beta emitters (i.e., ^{90}Sr) are estimated using a variety of methods.

Sampling and Analysis Frequency

Sampling frequencies are determined based on the potential for detecting elevated external radiation levels and for public exposure. Equipment limitations can be important, as in the case of the widely used TLD. The minimum detectable integrated exposure of the currently used system is ~5 mR, and exposure times that produce at least 15 to 20 mR are recommended for the desirable “2 sigma” (95% confidence level) values. The potential for detecting external radiation levels caused by current onsite operations is insignificant at most offsite locations, as opposed to onsite locations that have variable and greater potential. Sampling frequencies for onsite surveys and TLDs require adjustments that reflect changes such as potential for loss of control of radiation and modifications in operations or transportation of radiation sources. If intermittent or sporadic operations have significant potential for elevating environmental exposures, survey frequencies are adjusted. Established communication channels with Hanford Site contractors are used to acquire current operational information.

The exchange frequency for all TLDs is quarterly because approximately this much exposure time is needed to generate statistically confident results above the limit of detection. Frequencies for TLDs in significantly elevated exposure areas such as the 100-N Area shoreline were monthly because this exposure period was long enough to provide statistically confident results and because this is an area of significance for detecting potential public exposures. The frequency has been changed to improve the statistical confidence (longer exposures), to reflect the slight decrease in exposure levels along the 100-N Area shoreline, and to make the TLD collection cost efficient. If sampling periods shorter than 1 mo are needed, pressurized ionization chambers or exposure meter measurements are used.

The pressurized ionization chamber measurements are continuously taken at prevailing downwind offsite locations. “Running” average exposure rates are displayed on a liquid crystal display, and averages are transferred to a removable data cartridge. The exposure rate data on the cartridge are collected monthly and transferred to a spreadsheet file for evaluation by PNNL staff. The data are plotted and posted at community-operated environmental surveillance stations for public information.

Frequencies for instrument surveys vary and are set to be approximately proportional with the potential for detecting elevated exposure to the public. Some onsite surveys, such as all waste-site, road, and rail surveys, are performed by Waste Management Federal Services of Hanford, Inc. and will be considered in establishing frequencies. Shoreline surveys are performed quarterly to coincide with TLD exchange dates for efficiency.

Sampling Location Selection

External radiation sampling locations are selected to accomplish the surveillance objectives. Several sources of information are used to help determine the potential for detecting increased exposures to the public. Some important factors that influence the determination of sampling locations are the radiation source characteristics, meteorology, geography, hydrology and sedimentation, population distribution, and recreational activities or lifestyles.

Although it appears that for public dose assessment there is little need to perform distant offsite external radiation monitoring for effects from airborne routine effluents or diffuse sources, selected sampling sites are maintained and concentrated around the local communities. There is a continual need for emergency preparedness dosimetry, confirmation of effluent controls, dose modeling, public assurance, and background monitoring. The fulfillment of these needs requires placement in strategic offsite locations that are generally upwind for the background location(s) and in population centers weighted toward prevailing wind directions (BNWL-SA-4534, BNWL-SA-4676). Because of the size of the Hanford Site, maximum predicted concentrations from airborne effluents are typically onsite, and sampling at these locations should continue even though the data do not indicate public exposures.

The effects of the river-transport pathway on external radiation levels have been studied because of the significant amount of radionuclides released into the Columbia River from past operations (PNL-3127). Liquid effluents from waste-water treatment, groundwater, and contaminated springs have generally continued to decrease, causing lower levels of external exposure-producing radionuclides in the Columbia River. At the same time, most of the elevated exposure areas on the shoreline and islands from radionuclides that have accumulated in the sediment have decreased because of physical decay. Although significant external exposure potential at accessible locations along the river appears to be decreasing, it is assumed that elevated radiation levels to which the public could be exposed will be detectable for many years. Because of extensive river usage by local inhabitants, exposure monitoring will continue with emphasis on characterizing potential radiation fields that may expose the public. The 100-N Area shoreline has the greatest potential for the detection of increased external exposure levels from onsite operations. A technical consideration in selecting associated sampling locations along the river is the fact that the shoreline levels change significantly with water-level fluctuations. This creates a variable when estimating a dose, based on stationary sampling points, to someone standing at the shoreline. This is addressed by intermittent exposure surveys (survey meter, pressurized ionization chamber, etc.) during seasons of recreational use. Selecting sampling locations is coordinated with water- and sediment-sampling locations for data comparability and support to the extent possible.

Before starting a new TLD sampling location, an initial survey is performed and documented to determine the natural radiation levels. Gamma spectroscopy, pressurized ionization chamber measurements, micro-rem meters, and/or soil-sample analyses are considered in initial survey characterizations.

A 1989 study (PNL-7124) confirmed the importance of characterizing the radionuclides contributing external dose at sample locations. That study determined that naturally occurring higher concentrations of ^{40}K and thorium caused some perimeter TLD results to be consistently higher than typical onsite or offsite samples.

Sampling locations for pressurized ionization chamber systems are not near large structures, in valleys, near atypical geologic strata, or at an unrepresentative altitude unless it is determined that such characteristics do not jeopardize the surveillance objective for that location.

Sampling or Measurement Methods Selection

Ambient whole-body external radiological dose integrations are currently performed using the Harshaw 8807 environmental dosimeter, consisting of two lithium fluoride (TLD-700) chips and two calcium fluoride dysprosium (TLD-200) chips (reserved for emergencies). The TLD-700 chips are preferred over others because of their relatively energy-independent response, tissue-equivalent atomic mass, and minimal fade when deployed for extended periods.

The pressurized ionization chamber system is used at various offsite and onsite locations to accurately measure instantaneous whole-body exposure rates from gamma photons or X-rays with energies greater than 70 keV. The system has computer memory capability to record average exposure rates over varying lengths of time and to integrate total exposures. The manufacturer-published accuracy for the system is ±5% at background levels, with a range extending to 100 mR/h.

Routine external exposure-rate surveys along the Columbia River are performed using micro-rem meters. The Bicron micro-rem meter detector utilizes a tissue-equivalent organic scintillator to measure dose rate. The energy response of the micro-rem meter is approximately flat for photon energies above 40 keV.

Routine contamination surveys by hand-held instruments are performed using the Geiger-Müller survey meter. Geiger-Müller meters are used for measuring surface contamination levels for beta or gamma emitters; results are reported in counts per minute and used to interpret compliance with regulatory limits. Although alpha-emitting radionuclides typically do not pose significant external radiation problems, the use of portable alpha survey equipment, such as an alpha scintillation probe/meter, is required when there is a concern about isolated alpha-emitter contamination.

Sample-Handling/-Treatment Methods

The TLDs are collected in a manner to ensure accurate exposures by appropriately shielding them in lead containers before and after deployment. The TLDs are handled in transport with consideration for keeping them unexposed to significant external radiation fields that would generate false-positive data. Comments describing any unusual handling of TLDs or any findings that may affect TLD results are recorded on the Environmental Monitoring Trip Log. Sample-collection and -handling procedures are documented in PNL-MA-580, Rev. 2.

Analytical Methods

Ambient dose is measured at TLD stations using one Harshaw 8807 environmental dosimeter, consisting of two lithium fluoride (TLD-700) chips and two calcium fluoride dysprosium (TLD-200) chips. The Harshaw card is contained in a sealed plastic holder. This dosimeter provides both shallow- and deep-dose measurement capability. The TLD is mounted on a plastic pipe attached to a metal post at ~1 m above the ground. The two TLD-700 chips at each site are read and averaged to determine the routine exposure (or dose). The two TLD-200 chips are read and reported only as necessary following emergency conditions.

Harshaw series 8800 automated reader systems are used to process all Hanford Site environmental dosimeters. A specific time-temperature profile processing protocol is followed for environmental dosimeters. Only the dosimetric portions of the respective TLD-200 and TLD-700 glow curves are used to calculate dose.

Quality Control Methods

The most important quality control features in this task are the calibration, maintenance, and audits of the TLD reading/recording system; calibration and maintenance of survey instruments; anomalous data-tracking system; Radiation Protection Technologist training; and procedures and records maintenance. The quality control for TLDs is established pursuant to the Standards-Based Management System (PNNL 1997). Intercomparison studies have been conducted to determine and document TLD processing performance. Some stations are collocated with the State of Washington Department of Health TLDs for intercomparison of results. Survey instruments are calibrated to American National Standards Institute N42.17, using radiation sources and standards traceable to the National Institute of Standards and Technology. Check source tests of detection equipment are routinely performed before, during, and after (when required) surveys. The pressurized ionization chamber system is returned to the factory for calibration and maintenance periodically. The anomalous data-tracking system in the environmental database is used to perform initial screening of TLD data (discussed in the subsection entitled Quality Assurance and Quality Control).

Reporting/Alarm Levels

Anomalous TLD results are flagged by computer screening of reported data as they are entered into the project database. Investigation into an anomalous result includes, as necessary, verification of the quality of the result (sampling and analytical aspects), questioning the operators of facilities near the location with anomalous results about unusual situations, reviewing nearby air-sampling results, and possibly following up with immediate portable instrument measurements and/or gamma spectroscopy. Reporting levels for TLDs and pressurized ionization chambers have not been set because these instruments are not capable of reliably detecting an annual incremental dose of 1 mrem EDE above background, and measurements of environmental media are more capable of detecting events that could lead to a 1-mrem EDE incremental external dose.

Exceptions

Neutron dose detection currently is not of concern in environmental measurements because no significant potential sources for public exposure have been identified. Facility construction, security, and distances to public access points eliminate the potential for any public exposure to significant neutron fields.

Potential submersion skin doses to members of the public are estimated from effluent data and are included in dose calculations for the EDE to members of the public. Although TLDs do perform some beta detection, potential skin dose to the public is currently not considered significant and is not reported in TLD results.

Onsite or offsite continuous gamma spectroscopy has not been used to detect environmental exposures because the cost has not been justified by current operations and effluent levels. Gamma spectroscopy has been used and is available for the characterization of photon-emitting radionuclides at various onsite and offsite locations.

Shoreline exposure measurement locations are not typically established at key water-sampling locations at the site boundary (along the Columbia River) because concentrations of radionuclides in water are routinely low enough not to cause any significant external exposure. If water sampling is performed in areas where the concentration levels are suspected to be high enough to cause external exposures, exposure measurements are made.

Dose Assessment Methods

The radiological dose that the public potentially receives during a calendar year from Hanford Site operations is calculated in terms of the “effective dose equivalent” (EDE). These dose quantities are given in units of millirem (mrem) (millisievert [mSv]) for individuals and in units of person-rem (person-Sv) for the collective dose received by the total population within an 80-km radius of the site. These quantities provide a way to uniformly express the radiological dose, regardless of the type or source of radiation or the means by which it is delivered. This subsection describes how the doses are calculated.

Releases of radionuclides from Hanford Site activities are usually too low to be measured in offsite air, drinking water, and food crops. Therefore, in most cases, the dose calculations are based on measurements made at the point of release (stacks and effluent streams), and environmental concentrations are estimated from these effluent measurements by environmental transport models.

The transport of radionuclides from the release source to the point of exposure is predicted by empirical models of exposure pathways. These models calculate concentrations of radionuclides in air, water, and food. Radionuclides taken into the body by inhalation or ingestion may be distributed among different organs and retained for various times. In addition, long-lived radionuclides deposited on the ground become possible sources for long-term external exposure and uptake by agricultural products. Dietary and exposure parameters are applied to calculate radionuclide intakes and radiological doses to the public. Standardized computer programs are used to perform the calculations. These programs contain internally consistent mathematical models that use site-specific dispersion and uptake parameters. These programs are incorporated in a master code, GENII (PNL-6584), which employs the dosimetry methodology described in reports by the International Commission on Radiological Protection(1979a, 1979b, 1980, 1981a, 1981b, 1982a, 1982b, 1988). The assumptions and input data used in these calculations are described below.

Types of Dose Calculations Performed

Calculations of radiological doses to the public from radionuclides released into the environment are performed to demonstrate compliance with applicable standards and regulations.

The DOE requires that estimates of radiation exposure to the general public be in EDE terms. The EDE represents the total risk of potential health effects from radiation exposure. The adoption and use of the EDE were previously recommended by the International Commission on Radiological Protection (1977). In addition to implementing the EDE requirement for offsite population dose calculations, DOE has also adopted the biokinetic models and metabolic parameters for radionuclides given by the International Commission on Radiological Protection in 1977 for estimating radiological dose. As in the past, when concentrations of radionuclides in the environment are too low to measure, DOE specifies that the doses are to be calculated from effluent data using environmental transport and dosimetry models.

The calculation of the EDE takes into account the long-term (50-yr) internal exposure from radionuclides taken into the body during the current year. The EDE is the sum of individual committed (50-yr) organ doses multiplied by weighting factors that represent the proportion of the total health-effect risk that each organ would receive from uniform irradiation of the whole body. Internal organs may also be irradiated from external sources. The external exposure received during the current year is added to the committed internal dose to obtain the total EDE. The EDE is frequently expressed in rem (or millirem), with the corresponding value in sievert (or millisievert) in parentheses. The numerous transfer factors used for pathway and dose calculations have been documented in GENII (PNL-6584) and in PNL-3777 Rev. 2.

The following types of radiological doses are estimated:

- "boundary" dose rate (millirem per hour and millirem per year) - The external radiological dose rates during the year in areas accessible by the general public are determined from measurements obtained near operating facilities.

- "maximally exposed individual" dose (millirem) - The maximally exposed individual is a hypothetical person living at a particular location who has a postulated lifestyle conducive to receiving higher radiological doses than other members of the public would be likely to receive. All potentially significant exposure pathways to this hypothetical individual are considered, including the following:

  - inhalation of airborne radionuclides

  - submersion in airborne radionuclides

  - ingestion of foodstuffs contaminated by radionuclides deposited on vegetation and the ground by both airborne deposition and irrigation water drawn from the Columbia River downstream of Hanford Site discharges

  - exposure to ground contaminated by both airborne deposition and irrigation water

  - ingestion of fish taken from the Hanford Reach of the Columbia River

  - recreation along the Hanford Reach of the Columbia River, including boating, swimming, and shoreline activities.

- 80-km population doses (person-rem) - Regulatory limits have not been established for population doses. However, evaluation of the collective population doses to all residents within an 80-km radius of the Hanford Site is required by DOE Order 5400.5. The 80-km population dose represents the summed products of the individual doses for the number of individuals involved for all potential exposure pathways.

The pathways assigned to the maximally exposed individual are assumed to be applicable to the offsite population. Consideration is given, however, to the fraction of the offsite population actually affected by each pathway. The exposure pathways for the population are as follows:

- drinking water - The Cities of Richland and Pasco obtain their municipal water directly and Kennewick indirectly from the Columbia River downstream of the Hanford Site. A total population of ~70,000 in the three cities drinks water derived from the Columbia River.

- irrigated food - Columbia River water is withdrawn for irrigation of small vegetable gardens and farms in the Riverview area of Pasco in Franklin County. Enough food is grown in this district to feed an estimated 2,000 people. Commercial crops are also irrigated by Columbia River water in the Horn Rapids area of Benton County.

- river recreation - These activities include swimming, boating, and shoreline recreation. An estimated 125,000 people who reside within 80 km of the Hanford Site are assumed to be affected by these pathways.

- fish consumption - Population doses from the consumption of fish obtained locally from the Columbia River were calculated from an estimated total annual catch of 15,000 kg/yr (without reference to a specified human group of consumers).

Data

The data that are needed to perform dose calculations based on measured effluent releases include information on initial transport through the atmosphere or river, transfer or accumulation in terrestrial and aquatic pathways, and public exposure. By comparison, radiological dose calculations based on measured concentrations of radionuclides in food require data describing only dietary and recreational activities and exposure times. These data are discussed in the following sections.

Population Distribution and Atmospheric Dispersion

Geographic distributions of the population residing within an 80-km radius of the four Hanford Site operating areas are based on 1990 Bureau of the Census data (PNL-7803). These data influence the population dose by providing estimates of the number of people exposed to radioactive effluents and their proximity to the points of release.

Atmospheric dispersion data are recalculated each year and are given in the annual Hanford Site environmental data report for that calendar year (e.g., PNNL-11473). These data describe the transport and dilution of airborne radioactive material, which influences the amounts of radionuclides being transported through the air to specific locations.

Terrestrial and Aquatic Pathways

Important parameters affecting the movement of radionuclides within potential exposure pathways, such as irrigation rates, growing periods, and holdup periods, are provided in the annual environmental report (e.g., PNNL-11472). Certain parameters are specific to the lifestyles of either “maximally exposed” or “average” individuals.

Public Exposure

The potential offsite radiological dose is related to the extent of external exposure to or intake of radionuclides released from Hanford Site operations. Parameters describing the diet, residency, and river recreation assumed for “maximally exposed” and “average” individuals are tabulated in the annual environmental report (e.g., PNNL-11472).

Dose Calculation Documentation

The Hanford Environmental Dose Overview Panel has the responsibility for defining standard, documented computer codes and input parameters to be used for radiological dose calculations for the public near the Hanford Site. Only those procedures, models, and parameters previously defined by the Panel are used to calculate the radiological doses (PNL-3777 Rev. 2). The calculations are then reviewed by the Panel. Summaries of dose calculation documentation for this report are shown in Tables D.5 through D.9 in PNNL-11472 and Tables Dose.1 through Dose.8 in PNNL-11473.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Dosimetry Coordination

Dosimetry coordination is an ongoing activity that was initiated in 1975 to support DOE in developing and implementing methods for health and environmental risk assessment. Radiation dose and chemical exposure evaluations are required by DOE to be performed whenever potential environmental exposures exist. These evaluations are typically performed by the individual Hanford Site contractors for a variety of purposes. As directed by DOE, the approach used in risk evaluations and the presentation of the results must be technically consistent across the Hanford Site and in accordance with applicable regulations and DOE Orders.

Dosimetry coordination supports DOE by assessing regulatory requirements, recommending methods for implementing those requirements, and in providing an overview function to ensure that the requirements are met in a technically defensible and consistent manner across the site. Support to develop or maintain software, databases, and other methods used to assess environmental risks is provided. In addition, special projects are undertaken at the request of DOE to aid in resolving risk-related issues or assessing impacts of activities that take place at the site. The major activities are described below.

Hanford Environmental Dose Overview Panel

Administrative and technical support is provided to the Hanford Environmental Dose Overview Panel, which is comprised of representatives from Hanford Site contractors. The Panel strives to ensure that all environmental and health-risk assessments performed are conducted in a technically defensible and consistent manner. The Panel serves as the technical representative for DOE-RL in matters related to environmental and health-risk assessments for operations and facilities on the site.

The purposes of the Panel are the following:

- ensure that appropriate methods (as required by DOE or other regulatory agencies) are used for radiological and nonradiological risk assessments
- ensure that all environmental and health-risk assessments are technically consistent
- foster communication among the contractors regarding environmental and health-risk assessments.

The Panel normally meets quarterly and conducts other activities through working groups that meet as needed to resolve specific issues that arise during onsite risk-assessment activities. The working groups consist of Panel members and other onsite experts, as needed, to address the topics under consideration.

The Panel also supports a group of contractor staff members who serve as Panel-approved reviewers. The reviewers (who are not restricted to Panel members) are called on to review assessments by staff members who perform radiation-dose and chemical-exposure calculations with the use of computer codes or other methods. The reviewers ensure that appropriate methods, assumptions, and associated parameters were utilized in the calculations. Current recommendations approved by the Panel are documented in PNL-3777 Rev. 2. That document is revised periodically to reflect Panel-approved changes in methods and data used for risk assessments at the Hanford Site.

Support for Software, Databases, and Other Risk-Assessment Methods

This task is designed to provide an up-to-date, technically peer-reviewed, documented set of computer codes for calculating potential radiation doses resulting from radionuclides in the environment. Staff assigned to this task are responsible for maintaining and upgrading the environmental dosimetry codes and databases that are used to assess routine and accidental releases of radionuclides to the environment from Hanford Site facilities and operations. Master copies of the computer codes and libraries are maintained in protected storage with access on a use-only basis. This includes the master files for the GENII software system (PNL-6584) and the Panel-approved version of the CAP-88 code (EPA-402-B-92-001), an updated version of AIRDOS-EPA that is mandated by the EPA for use in some types of radiation dose calculations.

This task supported the production of the GENII software system, which represents the current-generation environmental dosimetry code developed for use at the Hanford Site. Distribution of the GENII software to Hanford Site users is provided on request, and a list of the current Hanford Site users is maintained. The code is also distributed to offsite users by the Radiation Safety Information Computational Center in Oak Ridge, Tennessee. The task logs all problem reports that are received from any GENII user and also provides information in the form of summary presentations to organizations or educational institutions regarding risk analysis methods used at the Hanford Site.

The GENII software package has been in use since 1988, and items that need updating in the code continue to be identified. As part of recent recommendations from national and international radiation protection organizations, the dosimetry models currently in use have been updated, and the revised models are expected to become part of the regulatory framework in the future. In anticipation of new regulatory requirements and to incorporate the results of other recent research in the field of environmental transport and effects of hazardous materials, cooperation is maintained with projects funded by other federal agencies to upgrade the GENII software package. Input from the Panel is critical to ensuring that the code upgrade meets the current needs of onsite users and that it implements models and assumptions required by regulatory standards.

Regulatory Review

It is important for the effective functioning of the Panel that the staff maintain their knowledge of current DOE Orders and other regulations published in the Federal Register. DOE Orders and other regulations that relate to the need for human health and environmental risk assessments are the focus of the regulatory review. The DOE Orders and other regulations, as well as DOE-HQ and DOE-RL guidance on human health protection, are used to help outline the necessary modifications to risk-assessment methods used at the Hanford Site.

Special Projects

Issues are routinely identified by DOE-RL or the Panel that may impact the data or methods used for Hanford Site risk assessments. These issues may be technical or regulatory in nature and are investigated by the project at the request of DOE or other onsite contractors.

Quality Assurance

Quality assurance is established and implemented through the Standards-Based Management System (PNNL 1997).

Independent surveillances and audits may be conducted by PNNL to ensure compliance.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Data Management, Analysis, and Statistical Treatment

Described herein are the objectives for management, analysis, and statistical treatment of surface environmental surveillance data. These objectives are primarily achieved through the use of HEIS. HEIS provides computer-based access to Hanford Site environmental sample data and is used to manage the data generated by the ongoing sampling efforts conducted on and around the Hanford Site.

Objectives

Good data management, data analysis, and statistical treatment practices are essential for the production of quality results. The objectives for analyzing environmental surveillance data are the following:

- manage data in a manner that ensures their timely collection, analysis, reporting, and validation in accordance with the master sampling schedule (e.g., PNNL-11464) and the traceability of results from scheduling to archiving in the environmental database
- estimate constituent-of-concern concentrations at each sampling and/or measurement point for each sampling and/or measurement time and estimate accuracy and precision
- compare the constituent-of-concern concentrations at each sampling and/or measurement point to previous concentrations measured at the same point to recognize changes or inconsistencies in concentration levels
- compare the constituent-of-concern concentrations at each sampling and/or measurement point to reporting limits
- compare the constituent-of-concern concentrations at individual sampling and/or measurement points to those measured at control or other points and evaluate the results of those comparisons.

Data Management Overview

HEIS is an operational system specifically designed for handling Hanford Site environmental information and data. HEIS is used to effectively manage data gathered during environmental monitoring activities at the Hanford Site. HEIS includes an integrated database and is intended to provide consistent and current information and data to its users; it enables the sharing of data by all Hanford Site personnel. The major components of HEIS are a database and a geographic information system (GIS). HEIS is implemented using current industry standards including a UNIX™ operating system, an Oracle database-management system, and a structured query language. The HEIS computer system is managed by Bechtel Hanford, Inc.

In accordance with the annual master sampling schedule (e.g., PNNL-11464), a schedule for collecting samples is established in the database at the beginning of each calendar year. Most samples for environmental surveillance are collected on a routine basis. Sample-identification labels and chain-of-custody forms are generated weekly by the database steward to facilitate sample collection. The database steward also generates laboratory composite sheets that identify individual samples to be combined to form composite samples. Analytical results are provided by the laboratories and reported in either electronic or hard-copy formats and entered into the database either electronically or manually. The database can also be used to produce various status and result reports to assist personnel in the review of data and to ensure the prompt identification of unusual results. Finally, analytical results stored in the database can be retrieved for review or for use in preparing reports (e.g., PNNL-11472).

UNIX is a registered trademark of Novell, Inc., San Jose, California.

Sample Scheduling

The cognizant PNNL manager and staff revise the calendar year sampling schedule to meet monitoring needs each year. The sampling locations, sample types, sample analyses, and frequencies of collection are identified and documented (e.g., PNNL-11464). In accordance with that schedule, the database steward establishes the scheduling information in the database at the beginning of each calendar year. Based on this information, the database-scheduling program interrogates itself to determine when a sample must be collected. The scheduled dates are automatically recalculated, based on the collection frequency, and are updated in the computer each week as the database steward generates the sample labels and chain-of-custody forms.

When a new sampling event is identified, the appropriate scheduling information is established in the database so that collection and analyses of the sample can occur.

Sample Collection

Most samples for environmental monitoring are collected on a routine basis. Sample-identification labels and chain-of-custody forms are generated weekly by the database steward to facilitate sample collection. The sample label identifies the task code (i.e., air, water, biota, soil, sediment, TLDs), HEIS sample-identification number, collection date, and analyses required. Once the sample is collected, the sample label is attached to the sample container and the sample is delivered to the analytical laboratory. The chain-of-custody form lists the samples to be collected on a given day and also identifies the task code, HEIS sample-identification number, sampling location, and date of collection. The chain-of-custody form accompanies the samples to the analytical laboratory, where the samples are relinquished into the custody of laboratory personnel. Laboratory personnel retain one copy of the signed chain-of-custody form; the other copy is returned to the database steward and becomes a permanent record that verifies sample collection, delivery, and receipt by the analytical laboratory. Sample-collection and -handling procedures are contained in PNL-MA-580, Rev. 2.

Each month, the database steward also generates composite sheets that identify individual samples to be combined to form composite samples. This information is forwarded to the analytical laboratory responsible for compiling the composite samples. On completion of the compositing process, laboratory personnel return the completed composite sheets to the database steward and they become a permanent record in the project files.

Tracking Sample Collection

The database is capable of tracking samples from the time the sample labels are produced until the sample results are entered into the database. This allows for accountability of both sample collection and sample analysis. When a sample label is generated (in the case of TLDs, when the chain-of-custody is generated), an accountability file is created for each analysis scheduled (i.e., radiochemical or chemical). After the sample is collected, the collection date, as identified on the chain-of-custody form, is entered into the database, satisfying the sample-collection portion of the accountability file.

The date the sample is submitted to the laboratory is also entered into the database. This date activates the sample-analysis-tracking feature in the accountability file (see Tracking Sample Analysis below).

Reporting of Analytical Data

Samples are analyzed for the constituents identified on the sample label, which can include radiochemical or chemical analyses. External radiation surveillance also occurs with the collection of TLDs. Results are reported in association with a 2-sigma overall propagated uncertainty. In the case of radiochemical results, a 2-sigma counting uncertainty is also reported. Data are reported by diskette or hard copy and are entered into the database either electronically or manually.

The minimum required data that are stored in the database include the following:

- HEIS sample-identification number
- sample location
- sample-collection date
- analysis
- result
- result unit
- sample volume
- comments as appropriate.

Data Validation

As radiochemical and TLD results are entered into the database, several mathematical tests are performed to determine whether the result is within the range of the established limits. The tests and supporting data include the following:

- Test 1: Was the minimum detectable concentration met?

- Test 2: Was the low limit exceeded?

- Test 3: Was the high limit exceeded?

- Statistics A: The maximum, minimum, and mean of the last 10 results of the same type for this sampling location are...

- Statistics B: The maximum, minimum, and mean of results for this same type at all locations for the previous 12 mo are...

As data are collected, the results are compared to previous results to help identify unusual measurements that require investigation or further statistical evaluation. If the result is unusual and fails any of the above tests, it is considered an anomaly and a 1-page anomalous data report is generated.

Outliers can represent a true extreme value or can indicate errors in sample collection, preparation, measurement, or equipment malfunctions. On request, the analytical laboratory will perform a data recheck, recount, or reanalysis to assist the task leader in determining the value of a questionable result. Following these investigations, the task leader, with the approval of the project manager, decides how to handle the suspect data. These decisions are documented on the anomalous data report, which becomes a permanent record in the project files.

Tracking Sample Analysis

To aid in the tracking of sample analyses, a maximum turnaround for reporting of results is established with the analytical laboratories. This turnaround, coupled with the sample submit date, provides an estimated due date for each analytical test ordered. If no result has been reported by the estimated due date, the database steward can generate a "late results" report. The late results report also indicates results that were reported late. An outstanding result will continue to appear on the late results report until the result is received and the accountability record has been completely satisfied.

Data Retrieval

One of the primary reasons for using a data-management system is to store data and provide efficient and easy access to the thousands of analytical results recorded each year. The database contains analytical data back to 1971, which can be retrieved by using Access®.

Database Security

To prevent the loss of data because of fire, power failure, or other causes, HEIS undergoes a complete backup three times a week by the Bechtel Hanford, Inc. computer systems manager. This backup is stored in a locked fireproof safe.

Quality Assurance

Records of data and other information developed during the operation of the HEIS are controlled and managed in compliance with the requirements in the PNNL quality assurance plan, which conforms to the requirements of DOE Order 5700.6C and 10 CFR 830.120 as interpreted and implemented by the Standards-Based Management System (PNNL 1997). HEIS database integrity is ensured through the use of rules and constraints implemented directly by the database (refer to BHI-EE-09 regarding HEIS software control).

Data Analysis and Statistical Treatment

Analytical results are reported and recorded with estimates of their uncertainty. Data sets are not truncated and include negative numbers. The database contains the same number of significant figures reported by the analytical laboratories, but summaries and reports may only include the appropriate number of significant figures. Results are reported as less than the estimated quantitative detection limit.

Data contained in the database vary in sample type (i.e., air, water, biota, soil, sediment, TLDs), and any subset of data of a given sample type may or may not fit probability distributions typical of that type for a variety of potential reasons (e.g., sample size, mixed populations). Therefore, routine statistical summaries obtained from the database are normally based on the arithmetic mean or median as measures of central tendency and on the range, standard deviation, and standard error of the mean as measures of dispersion.

Microsoft Access is a registered trademark of Microsoft Corporation, Redmond, Washington.

Statistical tests to determine differences and effects are based on parametric or nonparametric tests appropriate to the sample sizes, distributions of the particular data sets being tested, and hypothesis being tested.

Tests for precision and accuracy are addressed in the subsection entitled Quality Assurance and Quality Control.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Laboratory Procedures

All routine environmental surveillance samples are analyzed according to written analytical procedures. These procedures are described in general terms in this subsection and in detail in the Quanterra Environmental Services laboratory procedures manual and in PNNL department-specific procedures manuals. Contractual minimum detectable concentrations and contract-required detection limits for the various matrix/ analysis combinations and other analytical information are shown in Table III.A-1 for radiological analytes and in Table III.A-2 for chemical constituents. In practice, actual minimum detectable concentrations and method detection limits have historically been significantly lower for most analyses.

Table III.A-1. Radiological Monitoring Sampling Summary

Type of Analysis	Approximate Sample Size	Nominal Count Time	Minimum Detectable Concentration	Nominal Analysis Aliquot Size
Air				
Gross alpha	800 m^3	50 min	0.001 pCi/m^3	800 m^3
Gross beta	800 m^3	40 min	0.003 pCi/m^3	800 m^3
HTO[a]	10 m^3	250 min	0.3 pCi/m^3	5 m^3
^{14}C[b]	40 m^3	150 min	1.0 pCi/m^3	10 g of carbon
^{85}Kr[b]	0.5 m^3	150 min	2.0 pCi/m^3	0.5 m^3
^{90}Sr	20,000 m^3/station	100 min	0.01 pCi/m^3	1,500 to 20,000 m^3
^{129}I[c]	1,500 m^3/station	---	0.00001 pCi/m^3	800 m^3
^{131}I	800 m^3	100 min	0.01 pCi/m^3	800 m^3
Gamma scan (^{137}Cs)	5,500 m^3/station	100 min	0.01 pCi/m^3	1,500 to 7,700 m^3
Pu (isotopic)	20,000 m^3/station	1,000 min	0.000005 pCi/m^3	1,500 to 20,000 m^3
^{241}Am[b]	1,500 m^3/station	200 min	0.00005 pCi/m^3	1,500 to 20,000 m^3

Table III.A-1. (contd)

Type of Analysis	Approximate Sample Size	Nominal Count Time	Minimum Detectable Concentration	Nominal Analysis Aliquot Size
U (isotopic)	1,500 m^3/station	1,000 min	0.00005 pCi/m^3	1,500 to 20,000 m^3
River and Surface Water				
Gross alpha	500 mL	50 min	4.0 pCi/L	200 mL
Gross beta	500 mL	20 min	4.0 pCi/L	200 mL
^{3}H (lo)	500 mL	600 min	10 pCi/L	150 mL
^{3}H	100 mL	250 min	300 pCi/L	10 mL
^{89}Sr [(d)]	10 L	100 min	0.6 pCi/L	10 L
^{90}Sr	10 L	100 min	0.06 pCi/L	10 L
^{99}Tc	4 L	150 min	1.0 pCi/L	4 L
^{129}I	6,000 L water	---	0.000001 pCi/L	1,500 to 3,000 L
Gamma scan (^{137}Cs)	750 L water	1,000 min	0.01 pCi/L	750 L
Gamma scan (^{137}Cs)	4 L	100 min	6 .0 pCi/L	4 to 10 L
Pu (isotopic)	750 L water	1,000 min	0.0002 pCi/L	750 L
U (isotopic)	1 L	1,000 min	0.06 pCi/L	100 to 1,000 mL
Milk				
^{3}H	100 mL	250 min	300 pCi/L	10 mL
^{90}Sr	4 L	100 min	2.0 pCi/L	1 L
^{129}I	4 L	---	0.00001 pCi/L	3 to 4 L
^{131}I[(e)]	4 L	100 min	0.5 pCi/L	4 L
Gamma scan (^{137}Cs)	4 L	500 min	8 pCi/L	1 L
Fruit				
^{3}H	2 kg	250 min	300 pCi/L	10 mL (water)
^{90}Sr	500 g	200 min	0.005 pCi/g	100 g
^{129}I (LEPD)[(e)]	500 g	200 min	1.0 pCi/g	50 g
Gamma scan (^{137}Cs)	500 g	200 min	0.02 pCi/g	500 g
Pu (isotopic)	500 g	1,000 min	0.0004 pCi/g	100 g
Produce and Farm Products				
^{90}Sr	500 g	200 min	0.005 pCi/g	100 g
^{99}Tc	500 g	150 min	1.0 pCi/g	5 g

Table III.A-1. (contd)

Type of Analysis	Approximate Sample Size	Nominal Count Time	Minimum Detectable Concentration	Nominal Analysis Aliquot Size
Gamma scan (^{137}Cs)	500 g	200 min	0.02 pCi/g	500 g
$^{239,240}Pu$	500 g	1,000 min	0.0004 pCi/g	100 g
U (isotopic)	500 g	1,000 min	0.02 pCi/g	2 g
Beef				
^{90}Sr	500 g	100 min	0.005 pCi/g	100 g
Gamma scan (^{137}Cs)	500 g	200 min	0.02 pCi/g	500 g
Poultry				
^{90}Sr	200 g (muscle)	200 min	0.005 pCi/g	100 g
Gamma scan (^{137}Cs)	500 g (muscle)	200 min	0.02 pCi/g	500 g
Eggs (without shells)				
^{90}Sr	500 g	100 min	0.005 pCi/g	100 g
Gamma scan (^{137}Cs)	500 g	200 min	0.02 pCi/g	500 g
Wine				
^{3}H	500 mL	600 min	10 pCi/L	10 mL (distillate)
Gamma scan (^{137}Cs)	1 L	500 min	6.0 pCi/L	1 L
Fish Fillet				
^{90}Sr	500 g	100 min	0.005 pCi/g	100 g
^{99}Tc	500 g	150 min	1.0 pCi/g	5 g
Gamma scan (^{137}Cs)	500 g	200 min	0.02 pCi/g	500 g
U (isotopic)	500 g	1,000 min	0.02 pCi/g	2 g
Fish Carcass				
^{90}Sr	500 g	100 min	0.005 pCi/g	10 g
Gamma scan (^{137}Cs)	500 g	200 min	0.02 pCi/g	500 g
Geese and Game Birds				
^{90}Sr	500 g (bone)	100 min	0.005 pCi/g	10 g
^{99}Tc	500 g (muscle)	150 min	1.0 pCi/g	5 g
Gamma scan (^{137}Cs)	500 g (muscle)	200 min	0.02 pCi/g	500 g

Type of Analysis	Approximate Sample Size	Nominal Count Time	Minimum Detectable Concentration	Nominal Analysis Aliquot Size
Pu (isotopic)	500 g (liver)	1,000 min	0.0004 pCi/g	100 g
U (isotopic)	500 g (muscle)	1,000 min	0.02 pCi/g	2 g
Deer				
Gamma scan (^{137}Cs)	500 g (muscle)	200 min	0.02 pCi/g	500 g
^{90}Sr	500 g (bone)	100 min	0.005 pCi/g	10 g
Pu (isotopic)	500 g (liver)	1,000 min	0.0004 pCi/g	100 g
Rabbits				
^{90}Sr	500 g (bone)	100 min	0.005 pCi/g	10 g
Gamma scan (^{137}Cs)	500 g (muscle)	200 min	0.02 pCi/g	500 g
Pu (isotopic)	500 g (liver)	1,000 min	0.0004 pCi/g	100 g
Soil and Sediment				
^{90}Sr	1 kg	100 min	0.005 pCi/g	100 g
Gamma scan (^{137}Cs)	1 kg	200 min	0.02 pCi/g	650 g
Uranium (isotopic) (LEPD)[(e)]	1 kg	1,000 min	0.02 pCi/g	100 g
Pu (isotopic)	1 kg	1,000 min	0.0006 pCi/g	100 g
Native Vegetation				
Gamma scan (^{137}Cs)	500 g	500 min	0.02 pCi/g	500 g
^{90}Sr	500 g	200 min	0.005 pCi/g	100 g
Total U	500 g	---	0.01 pCi/g	20 g
Pu (isotopic)	500 g	1,000 min	0.0004 pCi/g	100 g
Direct Radiation Exposure				
Thermoluminescent dosimeter	4 chips per holder	---	1.0 mR[(e)]	---

--- = Not applicable.
(a) Tritiated water vapor.
(b) Not routinely analyzed for.
(c) Four locations.
(d) Absolute sensitivity in the manner it is used is well below 1 mrem.
(e) LEPD = low-energy photon detector.

Table III.A-2. Chemical Monitoring Sampling Summary

Constituent	Contract-Required Detection Limit Water, µg/L	Solids, µg/Kg
Metals		
Antimony	0.02	10,000
Arsenic	0.05	500
Beryllium	0.1	200
Cadmium	0.01	500
Chromium	0.2	1,000
Copper	0.1	2,000
Lead	0.02	30
Mercury	0.2	400
Nickel	0.1	2,500
Selenium	0.5	500
Silver	0.05	1,000
Thallium	0.02	500
Zinc	0.3	1,000
Anions[a]		
Chloride	200	
Fluoride	100	
Sulfate	500	
Nitrite	20	
Nitrate	20	
Volatile Organic Compounds[b]		
Acetone	5	
Benzene	5	
Carbon tetrachloride	5	
Chloroform	5	
p-Dichlorobenzene	5	
1,1-Dichloroethane	5	
1,2-Dichloroethane	5	
1,2-Dichloroethylene (cis and trans)	5	
Methylene chloride	5	
2-Butanone	5	
4-Methyl-2-pentanone	5	
Tetrachloroethylene	5	
Toluene	5	

Table III.A-2. (contd)

Constituent	Contract-Required Detection Limit Water, µg/L	Solids, µg/Kg
1,1,1-Trichloroethane	5	
1,1,2-Trichloroethane	5	
Trichloroethylene	5	
Vinyl chloride	5	
Total xylene	5	
1-Butanol	5	
Propionitrile	5	
Carbon disulfide	5	

(a) Method 300.0 (EPA-600/4-79-020).
(b) Method 8260 (SW-846).

Air Samples

Alpha- and beta-emitting radionuclides are measured by a direct count from the glass fiber filter (>99% efficient for 0.3-µm particles). Alpha radiation is counted on a low-background, gas-flow proportional counter; beta radiation is counted on a gas-flow proportional counter.

Gamma-emitting radionuclides are counted directly from glass fiber filters using lithium-ion drifted germanium (Ge[Li]) or hyperpure germanium (HPGE) detectors with a multichannel, pulse-height analyzer. Listed below are the radionuclides that are reported for detectable concentrations (i.e., when net counts exceed the 2-sigma total propagated analytical uncertainty):

^{7}Be[a]	^{54}Mn	^{65}Zn	^{106}Ru[a]	^{137}Cs[a]	^{152}Eu
^{22}Na	^{59}Fe	^{95}ZrNb	^{125}Sb[a]	^{140}BaLa	^{154}Eu[a]
^{24}Na	^{58}Co	^{99}Mo	^{131}I	^{140}Ce	^{155}Eu[a]
^{40}K[a]	^{60}Co[a]	^{103}Ru	^{134}Cs[a]	^{144}CePr	

(a) Routinely reported for all samples.

Strontium-90 is leached from glass fiber filters with fuming nitric acid, scavenged with barium chromate and ammonium hydroxide, precipitated as a carbonate, transferred to a stainless-steel planchet, and counted with a low-background, gas-flow proportional counter. After 15 d, the ^{90}Sr decay product is separated and counted with a proportional counter.

Uranium is leached from glass fiber filters with nitric acid, converted to the chloride form, and loaded onto an anion-exchange column. The effluent is then polonium decontaminated with ascorbic acid and copper disk treatment. The uranium is then extracted with anhydrous ether. The sample is then electrodeposited onto a stainless-steel planchet and counted with an alpha spectrometer to determine the uranium isotopic concentrations.

Plutonium is leached from glass fiber filters with nitric acid and passed through an anion-exchange resin. The plutonium on the resin column is eluted with hydrochloric acid containing ammonium iodide, electrodeposited on a stainless-steel disk, and then counted with an alpha spectrometer to determine the ^{238}Pu and ^{239,240}Pu concentrations.

Americium-241 concentrations are determined through the use of the eluate from the plutonium anion-exchange resin column. A calcium oxalate precipitation is performed. The americium is then extracted with dibutyl N,N-diethylcarbamylphosphate (DDCP) and passed through a cation-exchange resin column to remove iron and thorium. The americium is eluted from the resin with high-concentration hydrochloric acid, electrodeposited on a stainless-steel disk, and then counted by alpha spectrometry.

Tritium is collected as tritiated water vapor using silica gel. The water vapor is removed from the gel by heat and vacuum action, and then collected in a freeze trap. The tritium content of the water vapor is determined with a liquid scintillation spectrometer.

Iodine-131 is collected on triethylene-di-amine (TEDA)-treated activated charcoal (90% and 70% efficient for methyl iodine at 2.6 and 5.2 m^3/h, respectively) and then counted on either a Ge(Li) or HPGE detector with a multichannel, pulse-height analyzer.

Iodine-129 is collected on a special petroleum-based charcoal. Iodine is removed from the charcoal, purified, and determined by mass spectrometry.

Carbon-14 is collected as a carbon dioxide gas using soda lime. The carbon dioxide is released from the soda-lime sample with acid and injected into a benzene synthesizer instrument. The carbon dioxide is quantitatively converted to benzene through a series of catalytic reactions. The benzene product is mixed with scintillation solution and counted on a low-temperature, liquid scintillation counter.

Krypton-85 is collected using a gas cylinder. The air sample is purified using a specially constructed cryogenic chromatograph. The sample is passed through a series of cold traps to remove unwanted gases. The purified ^{85}Kr is then mixed with scintillation solution and counted on a low-temperature, liquid scintillation counter.

Water Samples

Alpha-emitting radionuclide (americium, neptunium, plutonium, and uranium) samples are treated with nitric acid and dried according to the methods given in SW-846. The residue is secured on a stainless-steel planchet using a collodion solution and counted with a low-background, gas-flow proportional counter.

Beta-emitting radionuclide samples are dried in the same way as the alpha-emitting radionuclides, and are then counted directly using a gas-flow proportional counter.

Gamma-emitting radionuclides are counted directly from 500 mL of sample concentrate using either a Ge(Li) or HPGE detector with a multichannel, pulse-height analyzer. See air samples discussion for a list of radionuclides included in gamma scan analysis.

Strontium-90 in large-volume water samples is measured in the same manner as in air samples, but the sample is acidified and boiled down, neutralized with ammonium hydroxide, and precipitated as the carbonate before exposure to fuming nitric acid.

Technetium-99 concentrations are determined using technetium separation by iron hydroxide precipitation followed by a carbonate precipitation. Further purification from interfering nuclides is performed by anion-exchange resin separation. The ^{99}Tc is counted by liquid scintillation spectrometry.

Tritium samples can be counted directly with a liquid scintillation spectrometer, or the sample can be enriched by alkaline electrolysis and then counted with a liquid scintillation spectrometer.

Uranium in the water sample is adsorbed onto anion resin following wet ashing, purified, electrodeposited onto a stainless-steel planchet, and then counted with an alpha spectrometer to determine uranium isotopic concentrations.

Filter-resin samples are analyzed for gamma-emitting radionuclides using either a Ge(Li) or HPGE detector with a multichannel, gamma-ray spectrometer. Aliquots of the resin samples are analyzed by chemical separation and alpha spectrometry for plutonium.

Iodine-129 analysis in water is determined by oxidation of the sample to “trap” the iodine on a charcoal absorber. The iodine is further processed and separated, loaded onto a thermal ionization mass spectrometer triple filament assembly, and counted on the mass spectrometer for iodine isotopic concentrations.

Volatile organic compounds are determined by SW-846 Methods 8010/8020, 8240 or 8260. Volatile compounds are introduced in the gas chromatograph by the purge-and-trap method. The components may then be further separated via the gas chromatograph and detected using a mass spectrometer.

For the determination of metals, samples are first digested in nitric acid. Some metals are determined by inductively coupled plasma/mass spectrometry (ICP/MS) and others by graphite furnace atomic absorption (GFAA) spectrometry using EPA-821/R-96-005 Method 1638 or EPA-821/R-96-006 Method 1639.

Mercury is determined by oxidizing the samples with bromine monochloride, which breaks down organomercury bonds. Mercuric ions in the oxidized sample are reduced to elemental mercury with tin chloride, and then purged onto a gold trap as a means of preconcentration and interference removal. Mercury vapor is thermally desorbed into the fluorescence pathway. Mercury is analyzed using cold vapor atomic fluorescence (CVAF) spectroscopy according to EPA-600/R-94-111 Method 245.1.

The anions (nitrate, nitrite, chloride, fluoride, and sulfate) are determined using EPA-600/4-79-020 Method 300.0. The sample is introduced into an ion chromatograph, and the anions of interest are separated and measured.

Milk

Gamma-emitting radionuclides in milk are counted directly using either a Ge(Li) or HPGE detector with a multichannel, pulse-height analyzer.

Tritium in water distilled from milk is counted directly with a liquid scintillation spectrometer.

Iodine-129 is separated from milk with an anion-exchange resin, purified, and analyzed by mass spectrometry.

Iodine-131 is removed from milk with an anion-exchange resin. The iodine is eluted with sodium hypochlorite, purified, precipitated as palladium iodide, and beta counted with a low-background, gas-flow proportional counter.

Strontium-90 is measured in the same manner as in air samples, but samples are purified with a cation resin, eluted with sodium chloride, and precipitated as a carbonate before exposure to fuming nitric acid.

Foodstuffs

Gamma-emitting radionuclides in foodstuffs are counted directly on either a Ge(Li) or HPGE detector with a multichannel, pulse-height analyzer.

Tritium in water distilled from farm produce is counted directly with a liquid scintillation spectrometer.

Iodine-129 in foodstuffs (other than milk) is determined after the sample is dried and weighed. The dried sample is counted directly with a low-energy photon detector (LEPD) system.

Plutonium-238 and ^{239,240}Pu in foodstuffs are measured in the same manner as in air samples, after samples have been dried, ashed in a furnace, and treated with nitric acid.

Strontium-90 is measured in the same manner as in air samples, but samples are dried, ashed in a furnace, and treated with nitric acid before exposure to fuming nitric acid.

For ^{99}Tc determination, the sample is digested to inorganic salts with nitric acid and hydrogen peroxide, and the digestate is processed in the same manner as for water samples.

Uranium isotopic concentrations in foodstuffs is dry and/or wet ashed to an inorganic salt. The salts are dissolved in nitric acid and extracted into hexone for purification. The sample is then electrodeposited onto a stainless-steel planchet and counted with an alpha spectrometer.

Vegetation and Wildlife

For ^{99}Tc determination, the sample is digested to inorganic salts with nitric acid and hydrogen peroxide and the digestate is processed in the same manner as for water samples.

Plutonium, strontium, uranium (isotopic), and gamma-emitting radionuclides are measured using the procedures described for foodstuffs.

Soil and Sediment

All soil and sediment samples are pretreated by weighing, drying, and ball milling to a constant particle size of 300 microns or less. Samples not requiring further pretreatment are counted directly to detect gamma- and low-energy photon-emitting radionuclides. For plutonium and strontium analyses requiring chemical separations, 1-g aliquots of samples are dissolved with concentrated acids by heating in pressurized containers in a microwave oven.

Gamma-emitting radionuclides are counted on either a Ge(Li) or HPGE detector with a multichannel, pulse-height analyzer after the sample is placed in a Marinelli beaker.

Plutonium and ^{90}Sr are measured after the sample is pretreated. Strontium is precipitated from the sample as strontium oxalate. The sample is then converted and precipitated as a carbonate; transferred to a planchet; and counted with a low-background, gas-flow proportional counter. After the strontium has been removed from the sample, the plutonium is coprecipitated with calcium oxalate, dissolved, and loaded onto an ion-exchange resin column. The plutonium is eluted from the resin column with nitric and hydrofluoric acids, deposited on a stainless-steel or platinum disk, and counted with an alpha spectrometer.

Uranium analysis is conducted after the sample is pretreated using an ion-exchange column. The sample is counted directly with an LEPD system.

Trace metals analysis is performed on designated soil and sediment samples by digestion using a nitric, perchloric, and hydorfluoric acid treatment with heating in a sealed teflon bomb. Methods 245.5 (cold vapor atomic adsorption [CVAA]) (EPA-600/4-79-020) and 200.9 (GFAA) (EPA-600/R-94-111) are used to determine mercury and other metals by GFAA and ICP/MS in the digestate.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Quality Assurance and Quality Control

In achieving the surveillance objectives identified in previous subsections, it is imperative that knowledge is maintained about the accuracy, precision, traceability, and limitations of data and information supporting project documentation. It is also imperative that an appropriate methodology to ensure control and legitimacy of project documentation are maintained. The quality of results is dependent on the control and verification of all components that provide input into the generation of reports and documentation. All components of work performed within the project are under an appropriate level of quality assurance (QA) and quality control (QC) scrutiny.

The goal of the QA/QC program is to ensure that accurate, defensible data are produced. This subsection describes the elements of the program and how they are implemented. In obtaining the QA/QC goal, a management commitment to operating a surveillance project that accurately reflects Hanford Site environmental impacts and radiation doses to the environment and public is required. Management commitment to QA/QC is ensured through PNNL-established management philosophies and is implemented through the Standards-Based Management System (PNNL 1997).

Requirements

The DOE QA requirements are contained in DOE Order 5700.6C, which replaced DOE Order 5700.6B as defined in DOE/EH-0173T. DOE Order 5700.6C requires that QA plans be developed and documented and recommends the judicious and selective application of appropriate and recognized standards. The DOE Order addresses 10 key elements but does not address environmental surveillance specifically. These requirements are implemented through the Standards-Based Management System (PNNL 1997), which gives direction for developing an activity-specific QA plan.

Quality Assurance Plan

Surface environmental surveillance is conducted under a project-specific QA plan. The QA plan addresses the 18 criteria of The American Society of Mechanical Engineers (ASME) NQA-1-1989 Edition, which meets the majority of the DOE Order 5700.6C requirements, and is approved by PNNL.

Assessments

Independent assessments are performed on project activities and procedures to ensure compliance with project, PNNL, and DOE QA requirements. These assessments are initiated by the DOE-RL program manager, the PNNL project manager, the media task leader, or the quality engineer on a routine and/or random basis. Assessment results are documented and then reported and reviewed by responsible management and media task leaders. Corrective actions are taken, documented, and verified as applicable.

Quality Control

Procedures

The QC for quality-affecting activities is maintained through written procedures. Quality-affecting activities and required written procedures are identified in the project-specific QA plan.

In addition, QA/QC for service functions is defined in statements of work issued to the performing functional organization, whether internal to PNNL or those of an external contractor. The PNNL service functions are performed according to the QA plan and procedures established for that function, unless the statement of work identifies special requirements.

Analytical Quality Control Program

Contracted analytical laboratories are required to maintain and participate in analytical QA programs to determine analytical precision and accuracy and to operate under written and approved procedures, as defined by a contract statement of work. Reports are generated periodically (monthly or quarterly) to summarize intralaboratory QC data and performance. The QC reports, minimum detectable concentrations, and method detection limit determinations are reviewed by the task leader; deficiencies are identified and investigated. Corrective actions are documented, implemented, and verified. In addition to the laboratory's internal QC program, participation in national intercomparison studies is required.

Radiochemistry. The majority of the intralaboratory QC program consists of analyzing blanks, replicates, and National Institute of Standards and Technology-traceable spike samples (which must comprise no less than 15% of all ordered tests) and maintaining data that validate determinations of current minimum detectable concentrations. Requirements for accuracy and precision for internal analytical QA are addressed below in Analytical Accuracy and Precision Criteria. Quarterly reports are generated to summarize intralaboratory QC data and performance. Use of Equation 37 from Chapter 6 in EPA 520/1-80-012 is designated for the determination of the minimum detectable concentration.

The contracted analytical laboratory participates in two national intercomparison studies. The laboratory is required to analyze applicable radionuclide-media samples from the DOE Quality Assessment Program operated by the Environmental Measurements Laboratory and the EPA Environmental Radioactivity Laboratory Intercomparison Studies Program. Additional QC data are generated by sending split or collocated (blind) duplicate samples to the laboratory and independent organizations (i.e., state, U.S. Food and Drug Administration, EPA) and challenging the laboratory with characterized (blind) reference samples as described in the project analytical QC plan. The characterized (blind) reference samples are developed to challenge the capabilities of the laboratory in areas of significance (important pathway radionuclide-media or historically weak analytical areas). Reference sample material is obtained from the National Institute of Standards and Technology, DOE, EPA, or other sources with a significant level of reliability and accountability. Criteria used for judging the performance on QC samples are derived from appropriate references (e.g., EPA-600/4-81-004, EML-587).

Reports of contractor performance in the DOE and EPA programs are required. Performances on blind samples (split or characterized reference) are evaluated by QC technical support personnel and reported to project management. These documents are reviewed and corrective actions (i.e., follow-up audits) taken if necessary.

The current radiochemistry analytical contract is with Quanterra Environmental Services, Richland, Washington, for all radiochemistry (except ^{129}I) analyses. PNNL performs ^{129}I analyses under a statement of work.

Chemical (Nonradiochemical) Analysis. The QC program for the chemical laboratories providing services consists of analyzing blanks, replicates, matrix spikes, matrix spike duplicates, and laboratory control samples. The QC data are reported with the sample results.

The laboratories participate in the EPA Water Pollution and Water Supply Performance Evaluation studies. Additional QC data are generated by sending split or collocated (blind) duplicate samples to the laboratory and independent organizations (i.e., state, EPA) and challenging the laboratory with characterized (blind) reference samples as described in the project analytical QC plan. Reference sample material is obtained from the National Institute of Standards and Technology, DOE, EPA, or other sources with a significant level of reliability and accountability.

Accuracy and precision requirements meet EPA reference procedure or program requirements or, in the case of a PNNL laboratory, the laboratory-specific QA plan requirements, which are:

	Water	Soil/Sediment
Accuracy	±25%	±25%
Precision	±20%	±25%

The EPA intercomparison programs reports of performance are required for the commercial laboratory performing analytical services for the project. Performances on blind samples (split or characterized reference) are evaluated by QC technical support personnel and reported to project management. These documents are reviewed and corrective actions (i.e., follow-up audits) taken if necessary.

The current commercial chemical analysis contract is with Quanterra Environmental Services, St. Louis, Missouri. Some metals analyses are performed by PNNL.

Analytical Accuracy and Precision Criteria

Radiochemical data-accuracy criteria call for analytical results of spiked samples to be within 20% to 30% of the known spike value. Accuracy is assessed using spiked samples and the criterion that 95% of the spiked sample results fall within the accuracy range given in Table III.A-3 for the various analysis types.

Precision requirements are met when replicate results (above detectable concentrations) fall within ±30% relative percent difference for water samples and within three standard deviations for all other media samples.

Table III.A-3. Accuracy Requirements

Type of Analysis	Precision
Gamma spectrometry	±20%
Liquid scintillation	±20%
Liquid scintillation with chemical separation	±30%
Alpha spectrometry	±25%
Beta proportional	±30%
Alpha proportional	±30%
Alpha-gamma coincidence	±25%
Beta-gamma coincidence	±25%
Uranium total, fluorimetry or phosphorimetry	±30%
Uranium isotopic, gamma (low-energy photon spectroscopy)	±30%

Accuracy and precision of analytical results are assessed by analyzing spikes, blanks, and replicate samples. Such samples comprise no less than 15% of all ordered radiochemical tests. For nonradiochemical tests ordered, QC criteria are defined above in Chemical Analysis. Spikes and blanks are included in each batch of samples. Spikes have, insofar as possible, the matrix, volume, and other relevant characteristics of the actual samples being analyzed. Blanks are matrix or reagent blanks. Reagent and sample media blanks will be analyzed with each batch of samples.

Field Radiation Survey Instruments

Field survey instruments are calibrated with appropriate radiation sources and standards traceable to the National Institute of Standards and Technology. Calibration methods and frequencies for field survey equipment are determined and controlled by the PNNL Radiation Standards and Calibration Project, which provides radiation calibration service (including pick up and delivery) to the Hanford Site. Special studies are performed periodically by technical support personnel to characterize detection capabilities of more complex instruments. Instruments are performance tested with appropriate check sources before and during (if required procedurally) surveys. Instruments determined not to be performing adequately are returned to the PNNL Radiation Standards and Calibration Project for maintenance and calibration.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

Records Management and Reporting

This subsection identifies and outlines the plans for record keeping and reporting to meet applicable requirements.

General record-keeping and reporting requirements are outlined in DOE Orders 5400.1 and 5400.5 and DOE/EH-0173T. These DOE Orders and guidance specify the reporting responsibilities, timing, and distribution of routine reports and contain some details on the required content and format. Requirements for preparing and distributing accident and occurrence reports are outlined in DOE Orders 225.1, 232.1, and 5484.1.

Record Keeping

DOE Order 5400.1 (pp. IV-3 and IV-8) and DOE Order 5400.5 (p. II-15) require the maintenance and retention of auditable records relating to environmental surveillance, the fate of radioactive materials in the environment and their impact on radiation doses to the public, records of calculations, computer programs, raw data, procedures, etc. Records are to be protected against damage or loss; generally, this means separate storage of duplicates. DOE Guide 1324.5B establishes requirements for the retention and disposal of environmental contamination measurement records, which apply to surveillance records. DOE Order 5700.6C establishes QA requirements.

These record-keeping requirements are implemented by the PNNL QA plan, which conforms to the requirements of DOE Order 5700.6C and 10 CFR 830.120 as interpreted and implemented by PNNL (1997).

Reporting

The reporting requirements applicable to environmental surveillance are contained in the following:

- DOE Orders 5400.1 and 231.1

  - annual Hanford Site environmental report to be submitted to DOH-HQ and the public by October 1 of the following year

    Surveillance results are formally reported through the annual Hanford Site environmental report (e.g., PNNL-11472). The distribution of the report is reviewed each year to ensure that potentially affected federal, state, and local governments and agencies; Indian Nations; environmental interests; business interests; and owners of Hanford Reach islands are notified concerning the environmental status of the site and surroundings.

  - preoperational environmental survey report

  - environmental monitoring plan to be reviewed annually and updated at least every 3 yr

    The monitoring plan is maintained per DOE Order 5400.1 and DOE/EH-0173T; the preoperational report will be prepared as directed by DOE-RL. Topical reports describing the fate of radioactive materials in the environment are issued periodically, for information not reportable through the reports listed above, to meet site-specific and public assurance needs.

- DOE Orders 225.1, 232.1, and 5484.1

  - occurrence reporting: submit emergency, unusual occurrence, or off-normal occurrence reports (e.g., environmental releases of significant offsite consequences, threatening or degrading to the environment, exceedances of compliance or administrative limits, or degradation of compliance monitoring systems)

  - notifications: submit notifications (e.g., damages, releases to the environment, occurrences resulting in press releases, or discovery of significant contamination)

    Occurrences are reported as required by the cited DOE Orders.

- DOE Order 5400.5

  - noncompliance: requires reporting when requirements will not be or have not been met (p. I-4)

  - potential doses exceeding reporting limits: requires reporting actual or potential exposures of the public that could result in either 1) a dose from DOE sources exceeding 10 mrem EDE in a year, or exceeding any limit or failing to meet any other requirement specified, or any other legal or applicable limits; or 2) a combined dose equal to or greater than 100 mrem EDE in a year from DOE and other anthropogenic sources.

Noncompliances with the DOE Order are reported as required.

Unusual results or trends in surveillance data that occur between issuances of the annual Hanford Site environmental report (e.g., PNNL-11472) are reported when they occur to DOE-RL and to the appropriate facility managers. Unusual report levels have been established, based on the environmental concentrations that would lead to an offsite public dose of either 1 or 10 mrem/yr, depending on the media, assuming that the condition persisted for an entire year. Unusual report levels to be utilized are shown in Table III.A-4.

Exceptions

No exceptions have been taken to *should** statements in DOE/EH-0173T.

References

ANSI (American National Standards Institute) N42.17. 1989. *Performance Specifications for Health Physics Instrumentation: (A) Portable Instrumentation for Use in Normal Environmental Conditions; (B) Occupational Airborne Radioactivity Monitoring Instrumentation; and (C) Portable Instrumentation for Use in Extreme Environmental Conditions*. Institute of Electrical and Electronics Engineers, Inc., New York.

ASME (The American Society of Mechanical Engineers) NQA-1-1989 Edition. 1989. *Quality Assurance Program Requirements for Nuclear Facilities, An American National Standard*. New York.

ARH-CD-775. 1976. *Geohydrologic Study of the West Lake Basin*. R. E. Gephart, P. A. Eddy, R. C. Arnett, and G. A. Robinson, Atlantic Richfield Hanford Company, Richland, Washington.

BHI-EE-09. *Environmental Data Management Procedures Manual*. In Library, ERC Controlled Manual List [Online]. Available URL: http://www.erc.rl.gov/

BNWL-90. 1965. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1964*. R. F. Foster and R. H. Wilson, Pacific Northwest Laboratory, Richland, Washington.

BNWL-316. 1966. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1965*. R. F. Foster, Pacific Northwest Laboratory, Richland, Washington.

BNWL-439. 1967. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1966*. J. F. Honstead, Pacific Northwest Laboratory, Richland, Washington.

Table III.A-4. Hanford Site Surface Environmental Surveillance Concentration Reporting Levels[(a)]

	^{3}H	^{60}Co	^{85}Kr	^{90}Sr	^{99}Tc	^{106}Ru	^{129}I	^{131}I	^{137}Cs	^{154}Eu	Natural U	^{234,5,8}U	$^{238,9/40}$Pu	^{241}Am
Air, pCi/m^3	1.2E+02	2.7E-01	3.0E+04	7.2E-02	(b)	1.8E-01	2.8E-03	4.7E-02	1.1E-01	---	---	8.0E-04	3.9E-04	---
River water, pCi/L	1.0E+04	1.7E+00	---	3.0E-01	8.4E+00	1.5E+00	7.3E-01	2.7E-00	3.5E-02	---	3.3E+00	3.3+00	1.1E+00	---
Drinking water, pCi/L	2.0E+04	5.0E+01	---	1.0E+01	6.2E+02	(c)	5.0E+00	3.0E+01	3.0E+01	---	(c)	5.0E+00	(c)	---
Dairy products, pCi/L	5.4E+04	(c)	---	2.7E-01	---	(c)	1.3E+01	8.1E+01	8.1E+01	---	---	(c)	(c)	---
Meats, poultry, eggs, pCi/g wet weight	1.8E+02	(c)	---	9.1E-02	---	(c)	(c)	(c)	2.7E-01	---	---	(c)	(c)	---
Cereals and grains, pCi/g	1.8E+02	(c)	---	9.1E-02	---	(c)	(c)	(c)	2.7E-01	---	---	(c)	2.5E-01	---
Leafy vegetables, pCi/g	5.0E+02	(c)	---	2.7E-01	1.5E+01	(c)	1.3E-01	(c)	6.0E-01	---	---	(c)	(c)	---
Fruit and other vegetables, pCi/g	5.0E+01	(c)	---	2.5E-02	1.3E+00	(c)	1.2E-02	(c)	6.0E-02	---	---	1.1E-01	6.2E-02	---
Wine,[(d)] pCi/L	2.0E+05	---	---	(c)	---	---	(c)	(c)	3.0E+02	---	---	(c)	(c)	---
Wildlife meats,[(e)] pCi/g	---	9.1E-01	---	1.8E-01	1.1E+01	---	---	---	5.4E-01	---	---	9.5E-01	5.0E-01	---
Soil,[(f)] pCi/g	(c)	(c)	---	3.0E-01	---	(c)	(c)	(c)	5.8E+00	---	8.0E+00	3.E+00	3.7E+00	5.5E-01
Vegetation and alfalfa, pCi/g	(c)	(c)	---	1.5E+00	1.6E+02	(c)	(c)	(c)	2.7E-01	---	1.3E+01	6.6E+00	4.2E+03	---
Sediment, pCi/g	(c)	1.4E+00	---	3.0E+04	(c)	1.4E+011	(c)	(c)	6.0E+00	2.6E+00	(c)	5.0E+01	8.1E+04	---

--- = Not applicable.
(a) Concentrations are shown to two significant figures for consistency, but this does not imply the analytical precision, which varies with measurement type, or the precision of the dose model used.
(b) Not routinely analyzed and/or not considered a significant dose contributor.
(c) Analysis is not typically reported, but determinations of other reportable levels included this medium-radionuclide pathway dose contribution.
(d) Based on estimated maximally exposed individual consumption rate of 70 L (~100 bottles) of wine per year.
(e) Based on estimated maximally exposed individual consumption rate of 40 kg of wildlife meat per year (from fish, deer, fowl, etc.); tritium concentrations are accounted for in fish only (not other wildlife types) from the river-water pathway calculation.
(f) Reporting levels for ^{90}Sr and ^{137}Cs in soil based on ~10 mrem effective dose equivalent.

BNWL-983. 1969. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1967*. J. P. Corley and C. B. Woolridge, Pacific Northwest Laboratory, Richland, Washington.

BNWL-1341. 1970. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1968*. W. L. Fisher and C. B. Wilson, Pacific Northwest Laboratory, Richland, Washington.

BNWL-1505. 1970. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1969*. J. P. Corley, Pacific Northwest Laboratory, Richland, Washington.

BNWL-1669. 1973. *Environmental Surveillance at Hanford for CY-1970*. J. P. Corley, Pacific Northwest Laboratory, Richland, Washington.

BNWL-SA-4534. 1973. *An Analytical Technique for Distributing Air Sampling Locations Around Nuclear Facilities*. D. A. Waite, Battelle, Pacific Northwest Laboratories, Richland, Washington; presented at Health Physics Society Annual Meeting, June 17, 1973, Miami, Florida.

BNWL-SA-4676. 1973. *Analysis of an Analytical Technique for Distributing Air Sampling Locations Around Nuclear Facilities*. D. A. Waite, Battelle, Pacific Northwest Laboratories, Richland, Washington; presented at the Third International Congress on International Radiation Protection Association, September 9 through 14, 1973 in Washington, D.C.; published as CONF-73090-P1, pp. 406-410.

10 CFR 830.120, Code of Federal Regulations, Title 10, Part 830, Chapter 120. *Nuclear Safety Management, Quality Assurance Requirements*.

40 CFR 61, Code of Federal Regulations, Title 40, Part 61. *National Emission Standards for Hazardous Air Pollutants*.

Comprehensive Environmental Response, Compensation, and Liability Act of 1980, as amended, Public Law 96-510, 94 Stat. 2767, 42 USC 9601 et seq.

DOE/EH-0173T. 1991. *Environmental Regulatory Guide for Radiological Effluent Monitoring and Environmental Surveillance*. Assistant Secretary for Environment, Safety and Health, U.S. Department of Energy, Washington, D.C.

DOE/EM-0327. 1997. *Accelerating Cleanup: Focus on 2006, Discussion Draft*. Office of Environmental Management, U.S. Department of Energy, Washington, D.C.

DOE Guide 1324.5B. “Implementation Guide for Records Management.”

DOE Order 225.1. “Accident Investigations.”

DOE Order 231.1. “Environment, Safety, and Health Reporting.”

DOE Order 232.1. “Occurrence Reporting and Processing of Operations Information.”

DOE Order 5400.1. “General Environmental Protection Program.”

DOE Order 5400.5. “Radiation Protection of the Public and the Environment.”

DOE Order 5484.1. "Environmental Protection, Safety, and Health Protection Information Reporting Requirements."

DOE Order 5700.6B. "Quality Assurance."

DOE Order 5700.6C. "Quality Assurance."

DOE/RL-96-92. 1996. *Hanford Strategic Plan*. U.S. Department of Energy, Richland, Washington.

Ecology (State of Washington Department of Ecology), EPA (U.S. Environmental Protection Agency), and DOE (U.S. Department of Energy). 1989. *Hanford Federal Facility Agreement and Consent Order Between the U.S. Environmental Protection Agency, the U.S. Department of Energy, and the State of Washington Department of Ecology, May 15, 1989*, as amended. Olympia, Seattle, and Richland, Washington.

EGG-10617-1062. 1990. *An Aerial Radiological Survey of the Hanford Site and Surrounding Area, Richland Washington - Date of Survey: July-August 1988*. Remote Sensing Laboratory operated for DOE by EG&G/EM, Idaho Falls, Idaho.

EML-587. 1997. *Semi-Annual Report of the Department of Energy, Office of Environmental Management, Quality Assessment Program*. C. G. Sanderson, and P. Greenlaw, Environmental Measurements Laboratory, U.S. Department of Energy, New York.

EPA-402-B-92-001. 1992. *User's Guide for CAP88-PC, Version 1.0*. B. S. Parks, Office of Radiation Programs, U.S. Environmental Protection Agency, Las Vegas, Nevada.

EPA-520/1-80-12. 1980. *Upgrading Environmental Radiation Data: Health Physics Society Committee Report HPSR-1*. Office of Radiation Programs, U.S. Environmental Protection Agency, Washington, D.C.

EPA-600/4-79-020. 1983. *Methods for Chemical Analysis of Water and Wastes*. U.S. Environmental Protection Agency, Cincinnati, Ohio.

EPA-600/4-81-004. 1981. *Environmental Radioactivity Laboratory Intercomparison Studies Program: Fiscal Year 1980-81*. A. B. Jarvis and L. Siu, U.S. Environmental Protection Agency, Las Vegas, Nevada.

EPA-600/4-82-055. 1982. *Methods for Chemical Analysis of Water and Wastes*. U.S. Environmental Protection Agency, Washington, D. C.

EPA-600/R-94-111. 1994. *Methods for the Determination of Metals in Environmental Samples, Supplement I*. U.S. Environmental Protection Agency, Washington, D.C.

EPA-821/R-96-005. 1996. *Determination of Trace Elements in Ambient Waters by Inductively Coupled Plasma-Mass Spectrometry (Draft)*. U.S. Environmental Protection Agency, Washington, D.C.

EPA-821/R-96-006. 1996. *Determination of Trace Elements in Ambient Waters by Stabilized Temperature Graphite Furnace Atomic Absorption (Draft)*. U.S. Environmental Protection Agency, Washington, D.C.

HEDL. 1981. *Chapter 18, FFTF Technical Specifications, FFTF Final Safety Analysis Report*. Hanford Engineering Development Laboratory, Richland, Washington.

HNF-EP-0573-5. 1997. *Hanford Site Near-Facility Environmental Monitoring Annual Report, Calendar Year 1996*. C. J. Perkins, A. R. Johnson, B. M. Markes, S. M. McKinney, R. M. Mitchell, and R. K. Price, Fluor Daniel Hanford, Inc., Richland, Washington.

HW-69369. 1962. *A Compilation of Basic Data Relating to the Columbia River Section 8 - Dispersion of Reactor Effluent in the Columbia River*. J. K. Soldat, General Electric, Richland, Washington.

HW-80991. 1964. *Evaluation of Radiological Conditions in the Vicinity of Hanford for 1963*. R. F. Foster and R. H. Wilson, U.S. Atomic Energy Commission, Washington, D.C.

International Commission on Radiological Protection. 1977. *ICRP Publication 26, Recommendations of the International Commission on Radiological Protection*. Annals of the ICRP, Vol. 1, No. 3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1979a. *ICRP Publication 30, Part 1, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 2, No. 3/4, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1979b. *ICRP Publication 30, Supplement to Part 1, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 3, No. 1-4, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1980. *ICRP Publication 30, Part 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 4, No. 3/4, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1981a. *ICRP Publication 30, Supplement to Part 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 5, No. 1-6, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1981b. *ICRP Publication 30, Part 3 Including Addendum to Parts 1 and 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 6, No. 2/3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1982a. *ICRP Publication 30, Supplement A to Part 3, Limits for Intakes of Radionuclides by Workers*. Annals of the ICRP, Vol. 7, No. 1-3, Pergamon Press, Elsmford, New York.

International Commission on Radiological Protection. 1982b. *ICRP Publication 30, Supplement B to Part 3 Including Addendum to Supplements to Parts 1 and 2, Limits for Intakes of Radionuclides by Workers.* Annals of the ICRP, Vol. 8, No. 1-3, Pergamon Press, Elmsford, New York.

International Commission on Radiological Protection. 1988. *ICRP Publication 30, Part 4, Limits for Intakes of Radionuclides by Workers: An Addendum*. Annals of the ICRP, Vol. 19, No. 4, Pergamon Press, Elmsford, New York.

PNL-3127. 1980. *Radiological Survey of Exposed Shorelines and Islands of the Columbia River Between Vernita and the Snake River Confluence*. M. J. Sula, Pacific Northwest Laboratory, Richland, Washington.

PNL-3777 Rev. 2. 1993. *Recommended Environmental Dose Calculation Methods and Hanford-Specific Parameters*. R. G. Schreckhise, K. Rhoads, J. S. Davis, B. A. Napier, and J. V. Ramsdell, Pacific Northwest Laboratory, Richland, Washington.

PNL-6464. 1988. *Environmental Monitoring at Hanford for 1987*. R. E. Jaquish and P. J. Mitchell, Pacific Northwest Laboratory, Richland, Washington.

PNL-6584. 1988. *GENII - The Hanford Environmental Radiation Dosimetry Software System*. B. A. Napier, R. A. Peloquin, D. L. Strenge, and J. V. Ramsdell, 3 volumes, Pacific Northwest Laboratory, Richland, Washington.

PNL-7124. 1989. *The Determination of the Penetrating Radiation Dose at Hanford*. L. A. Rathbun, Pacific Northwest Laboratory, Richland, Washington.

PNL-7803. 1991. *Hanford Area 1990 Population and 50-Year Projections*. D. M. Beck, B. A. Napier, M. J. Scott, A. G. Thurman, M. D. Davis, D. B. Pittenger, S. F. Shindle, and N. C. Batishko, Pacific Northwest Laboratory, Richland, Washington.

PNL-8150. 1992. *Methods for Estimating Doses to Organisms from Radioactive Materials Released into the Aquatic Environment*. D. A. Baker and J. K. Soldat, Pacific Northwest Laboratory, Richland, Washington.

PNL-8531. 1993. *Columbia River Monitoring: Distribution of Tritium in Columbia River Water at the Richland Pumphouse*. R. L. Dirkes, Pacific Northwest Laboratory, Richland, Washington.

PNL-8789. 1993. *Investigation of Exposure Rates and Radionuclide and Trace Metal Distributions Along the Hanford Reach of the Columbia River*. A. T. Cooper and R. K. Woodruff, Pacific Northwest Laboratory, Richland, Washington.

PNL-MA-580, Rev. 2. 1996. *Surface Environmental Surveillance Procedures Manual*. R. W. Hanf and R. L. Dirkes, eds., Pacific Northwest National Laboratory, Richland, Washington.

PNNL. 1997. "Subject Areas (Standards, Procedures and Guidelines), A-Manuals." In *Standards-Based Management System* [Online]. Available URL: http://wwwi.pnl.gov:2080/.

PNNL-6415 Rev. 9. 1997. *Hanford Site National Environmental Policy Act (NEPA) Characterization*. D. A. Neitzel (ed.), C. J. Fosmire, D. W. Harvey, D. J. Hoitink, D. A. Neitzel, P. D. Thorne, B. N. Bjornstad, R. A. Fowler, P. L. Hendrickson, D. J. Hostick, T. M. Poston, and M. K. Wright, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-10714. 1995. *Nonradiological Chemical Pathway Analysis and Identification of Chemicals of Concern for Environmental Monitoring at the Hanford Site*. M. L. Blanton, A. T. Cooper, and K. J. Castleton, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11464. 1997. *Environmental Surveillance Master Sampling Schedule*. L. E. Bisping, Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11472. 1997. *Hanford Site Environmental Report for Calendar Year 1996*. R. L. Dirkes and R. W. Hanf (eds.), Pacific Northwest National Laboratory, Richland, Washington.

PNNL-11473. 1997. *Hanford Site Environmental Data Report for Calendar Year 1996*. Pacific Northwest National Laboratory, Richland, Washington.

SW-846. 1986. *Test Methods for Evaluating Solid Wastes: Physical/Chemical Methods, 3rd ed.* Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency, Washington, D.C.

Turner, B. D. 1970. *Workbook of Atmospheric Dispersion Estimates*. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina.

WAC 173-201A, Washington Administrative Code. *Water Quality Standards for Surface Waters of the State of Washington*. Olympia, Washington.